

TECHNOLOGIE

APPAREILS INTERNATIONALES



6 HIGHLIGHTS OF 1988

10 ORGANIZATION OF TAI AND ITS SUBSIDIARIES

12 TECHNOLOGY PLANNING

14 GENERATION

14 Demonstration of the RUPA relay

15 Project SUPER

15 Vibration measurement on stator windings

16 Field tests on a robotized turbine-repair system

16 IRECA-Hydroloy welding electrodes

16 Optimum generation planning

16 Interpretation of discharge spectra

17 Emergency power-supply restoration of auxiliary services at Gentilly 2

17 Thermal stability of morpholine

17 Wind turbine-diesel generator systems

18 TRANSMISSION

18 EHV cable testing

19 Energy imports via Châteauguay substation

19 Revision of the transmission system design criteria

20 Research on insulating oils

20 Mechanical resistance of transformer tanks

20 Performance of gas insulation

20 HVDC wall bushings and cable terminations

21 Lightning-current measuring system

21 Biological effects of electric and magnetic fields

22 Phase-angle measuring system

22 Expert system for transformer diagnostics

22 Circuit-breaker testing

23 Critical levels for dissolved hydrogen in transformer oil

24 Effect of acid rain on power system hardware

24 Duncan Lake ground electrode

24 Mechanical tests

24 Mechanical characteristics of overhead lines

25 Fracture mechanics

25 Tests on 735-kV post insulators

25 Converter transformer testing

26 New criteria for low-temperature simulation of SF₆ circuit breakers

26 Calculation of electromagnetic interference

27 Single-phase reclosing at 315 kV

27 Load behavior modeling

27 Modeling of static var compensators

28 DISTRIBUTION

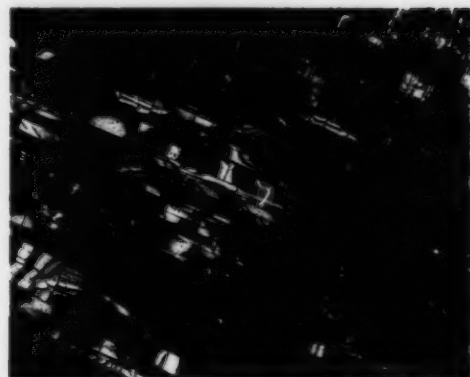
- 28 Second-generation supervisory-control system
- 29 Three-phase voltage unbalance
- 30 New current-limiting fuse design
- 30 Aging tests on composite insulators
- 30 Nuisance fuse operation on distribution transformers
- 31 Cables and accessories
- 32 Explosion of gases in manholes
- 32 Voltage detector
- 33 Tests on separable insulated connectors
- 33 Aluminum-copper connectors
- 33 Distribution system planning

34 INDUSTRIAL APPLICATIONS OF ELECTRICITY

- 34 Magnetic induction for heating calenders
- 35 Technological feasibility and design parameters for an infrared furnace
- 35 Studies conducted for industry
- 36 Prototype of high-power-density resistances
- 36 Chemical electrosynthesis
- 36 Mobile unit for plasma demonstration
- 37 Industrial applications of plasmas
- 37 Plasma pilot plant
- 37 Collaboration with universities

38 TEST TECHNIQUES AND MEASURING DEVICES

- 38 Automatic recorder for EHV transients
- 39 Data acquisition and control system for the cable-testing facility
- 39 New measuring system for the high-power laboratory
- 40 Safety of the internal insulation of power transformers
- 40 Amorphous materials for water electrolysis
- 40 Materials characterization laboratory
- 40 Testing of optical fibres



Crystals of hydroquinone (above) and tartaric acid (right) are photographed using an optical microscope.

41 DEVELOPMENT PROJECTS

- 41 Telerobotics-related activities
- 42 ACEP pilot plant
- 42 Intercontinental hydrogen transportation project
- 43 Task force on expert systems
- 43 Automation of the St-Laurent distribution control centre
- 43 Computer-assisted mapping
- 43 Remote control for dual-energy systems

44 LONG-TERM PROJECTS

- 44 Batteries for electric traction
- 45 Initial activities at the CCMF
- 45 Tokamak operation
- 45 High-frequency auxiliary system
- 45 Laser diagnostics
- 46 X-ray diagnostics
- 46 Theoretical and interpretation work
- 46 Superconductivity

47 NEW FACILITIES

- 47 New power system study and simulation centre
- 47 Underground-cable test facility
- 48 Additional facilities for LTEE
- 49 Fire protection system

50 MARKETING

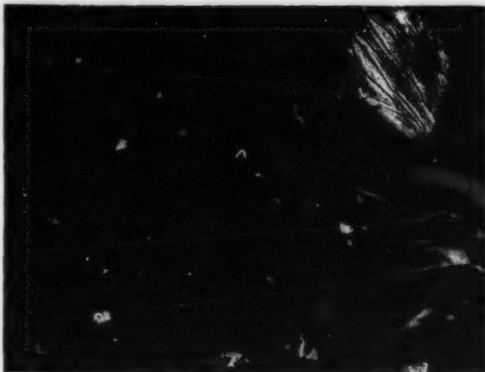
- 50 Creation of Strateck Technologies International
- 51 Marketing ALCID and SICC software
- 51 Marketing licence for Ferranti-Packard
- 52 Agreement with ASEA Brown Boveri
- 52 Marketing of the IREQ micro-ohmmeter

53 COLLABORATION WITH INDUSTRY

54 INTERNATIONAL ACTIVITIES

- 54 Africa
- 56 Asia
- 57 Latin America
- 58 Activities related to the Francophone Summit

59 AWARDS AND DISTINCTIONS



The words that spring to mind as I review the past year are continuity, consultation and expansion.

I must begin by emphasizing the continued support of our personnel, the men and women who devote their energies to research, testing, marketing, planning, overseas missions, office work and maintenance of our facilities. I take advantage of this opportunity to thank them for their contributions and to congratulate them on the outstanding quality of their work.

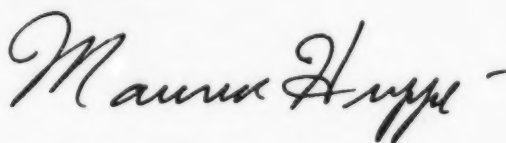
Consultation was central to our concerns throughout the year. The committees and task forces set up to prepare the first integrated Technology Plan drew together some 150 managers, researchers, engineers and specialists from throughout the utility. The plan defines the major orientations that will guide and support our technological development activities for the period 1989-1991. It also establishes the main areas of research together with the budget estimates.



Consultation was also the key to the daily exchanges between our scientific staff and the utility's technical personnel. Together, we defined the needs and developed mechanisms for establishing a customer-supplier relationship with the Hydro-Québec departments concerned. In the meantime, cooperation continued with outside partners – equipment manufacturers, electrical utilities, research centres and government agencies, both in Canada and abroad. We are proud of the harmonious and rewarding relationships we have developed with them. Lastly, 1988 saw considerable expansion, mainly in the number of facilities that TAI has acquired. The new power system study and simulation centre, for example, will double

the present capacity and allow simultaneous studies of the dynamic behavior of Hydro-Québec's transmission system. The cable-testing facility, for its part, will be used to study the components of the ± 450 -kV direct-current under-river crossing and test high-voltage alternating-current cables.

This report of activities bears witness to a most productive year. And 1989 promises to be equally rewarding, judging by the unstinting efforts of TAI personnel to ensure the utility's technological development and promote the use of electricity in industry.

A handwritten signature in dark ink, reading "Maurice Huppé". The signature is fluid and cursive, with a long horizontal stroke at the end.

Maurice Huppé
Executive Vice President
Technology, International
Affairs and IREQ

In the pursuit of its major objectives, TAI allocated \$96 million to research, development and demonstration activities in 1988. Government agencies, electrical utilities and industry contributed a further \$13 million for research and testing undertaken on their behalf. Meanwhile, Hydro-Québec International has made its parent company's technological expertise available to 20 or more countries throughout the world.

NEW FACILITIES

Major facilities were built this year for transmission-related research and testing: a new power system study and simulation centre and a test area for high-voltage underground cables.

The new study and simulation centre, a \$10-million investment which has twice the capacity of the existing centre, allows permanent simulation of the Hydro-Québec power system and simultaneous studies of its dynamic behavior: operation optimization studies for different facilities, planning studies for the revision of Hydro-Québec's transmission system design criteria, integration and commissioning studies for interconnections and compensation equipment, etc. The centre is scheduled to go into operation at the end of 1989.



The underground-cable testing facility has been built as part of the project involving construction of the DC line from James Bay to New England and the river crossing under the St. Lawrence. It will serve to study the components of this 450-kV bipolar link and their long-term performance. The test facility will also be used to study HVAC cables for voltages up to 735 kV, in particular for tests on 125-m loops of such cable, their bushings and related apparatus. This \$13-million facility will go into service in summer 1989.

POWER TRANSMISSION

Another activity related to the under-river crossing project is the development of a testing and demonstration program for studying prototype cables from three manufacturers. A considerable effort was devoted to perfecting instruments for analysing the thermal behavior of the under-river crossing and designing the ductwork, instrumentation and data-acquisition systems for the test area. Work also began on the development of a software package for analysis of the cable's loading capacity and on the simulation of the worst cable-operating conditions by means of short-circuit tests.

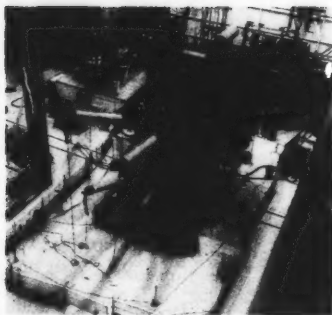


Researchers at the system study and simulation centre performed a study related to Hydro-Québec's effort to revise its transmission system design criteria. They also examined the possibility of importing energy from the United States via Châteauguay converter station.

Two projects related to the biological effects of electric and magnetic fields were launched during the year: the first on human perception of ionic fields and currents produced by DC lines, the second on characterization of electric and magnetic fields in the environment. Work continued on the dosimetry aspect of a joint epidemiological study with *Électricité de France* and Ontario Hydro.

Among other activities related to power transmission, mention might be made of the following:

- installation of the central unit of the phase-angle measuring system and construction of two new measuring units;
- a study for the Canadian Electrical Association on high-voltage fibre-optic links for control circuits;



- determination of critical levels for dissolved hydrogen in transformer oil;
- evaluation of the potential effects of acid rain on substation apparatus;
- preparation of standards on the mechanical performance of 735-kV transformer tanks subjected to explosive internal faults.

Meanwhile, activity in the large testing laboratories was intense. In the high-voltage laboratory, for example, tests were conducted on the first 404-MVA HVDC power transformers built by ASEA Brown Boveri for the new 450-kV DC bipolar line, and on wall bushings and HVDC cable terminations in the pollution test chambers. The high-power laboratory was the scene of current-breaking tests with the fault applied at the breaker terminals and short-line-fault tests at -50°C on a 735-kV SF_6 circuit-breaker module.



POWER GENERATION

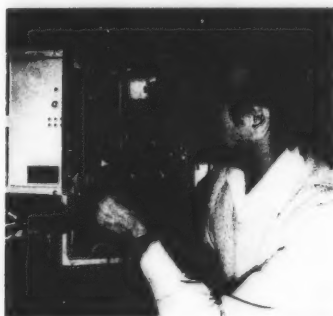
Various measuring, control, monitoring and maintenance systems for turbine generators were developed during the year:

- The universal relay for generator protection, RUPA, was installed at Carillon for demonstration purposes. It is planned to install 96 similar systems between now and 1992.
- SUPER, the permanent monitoring system for turbine-generators, has been operating for several months in a generating station, where it can be used to measure 50 of the parameters most representative of equipment status. Hydro-Québec plans to install 16 SUPER prototypes in 1989, and, as the project continues, will focus on developing suitable diagnostic tools.
- The new IRECA steel developed for repairing damage due to cavitation is now being marketed under the name of Hydroloy HQ 913.
- The compact robot for turbine repair that Hydro-Québec has developed in cooperation with Ontario Hydro was tested in a generating station, where it proved highly successful for grinding, gouging and welding.
- Capacitive transducers developed for measuring the vibrations of stator windings are now undergoing tests in a generating station.
- The third version of the NUMA model, an optimum-planning tool, has been completed and is now in use at Hydro-Québec for weekly generation planning purposes.

DISTRIBUTION

The diversity of distribution-related research activities in 1988 may be assessed from the following examples:

- A second generation of terminal units for supervisory control of distribution lines has been developed, and 83 devices have already been produced by a Québec firm for field installation in two of Hydro-Québec's administrative regions.
- Work was completed on the development of new software for distribution system planning. This software is now being used by planners in three Hydro-Québec regions for selecting the equipment needed for system expansion or upgrading programs.
- A study was performed of nuisance fuse operation during magnetic storms and mitigation methods were proposed.
- A new measuring and analysis technique has been proposed for improving the accuracy of evaluations of voltage unbalance on distribution systems.



- A patent has been obtained for a current-limiting fuse that uses a ceramic extinguishing medium.
- Work has also been conducted on extruded-cable aging, cable junctions, voltage detectors and explosions in underground vaults.

INDUSTRIAL APPLICATIONS

Hydro-Québec's electrochemical and electrical technology research laboratories, LTEE, undertook several projects during the year as part of their mandate to develop and demonstrate new industrial processes that use electricity. One such project is the production of a newly designed coil for heating the metal rolls used in the pulp and paper industry to dry and calender paper. Another is the development of an industrial prototype of a high-power-density electrical resistance, which is far more compact and inexpensive than conventional devices. LTEE has also developed an infrared furnace for drying flat, thick, heat-sensitive materials, purchased a continuous furnace combining infrared radiation and convection, and commissioned a 1-MW mobile unit for demonstration of the plasma technology and transfer of this technology to industry.



LONG-TERM PROJECTS

A study was conducted for Energy, Mines and Resources Canada on a 21-kWh battery installation for powering electric vehicles. Meanwhile, the Canadian Centre for Magnetic Fusion (CCMF) has taken over the activities related to the tokamak thermonuclear fusion project. The CCMF comprises Hydro-Québec, Atomic Energy of Canada Limited (AECL) and the *Institut national de la recherche scientifique*. The tokamak was operated for over 12 months for scientific purposes before being dismantled so that the internal coils and structures could be installed.

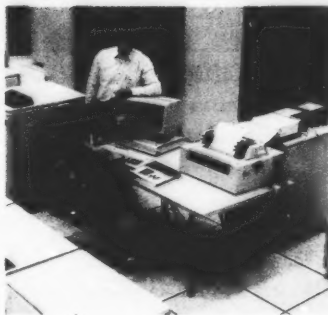
In the area of superconductivity, an industrial consortium has been set up with AECL and Canada Wire and Cable Limited to develop the technologies for manufacturing prototype superconductors. In addition, a study was performed to assess the potential applications of superconductivity in the electric utility industry.

DEVELOPMENT PROJECTS

Two new telerobotics projects began in 1988. First, the Canadian Electrical Association awarded the consortium comprising Hydro-Québec and the Montreal firm CAE Electronics a mandate to design, develop and test a remote manipulator arm for overhead distribution system maintenance. Second, Hydro-Québec, the Computer Research Institute of Montreal and McGill University signed an agreement to jointly develop a telerobotics software package. Negotiations have begun with battery and polymer-film manufacturers with a view to setting up a pilot installation for the ACEP (polymer-electrolyte) battery and assessing the market potential of room-temperature ACEP batteries.

In another area of research, a task force on expert systems has been created at Hydro-Québec for the purpose of developing different expert systems and promoting their use and commercial applications. Six related projects are now underway. Work continued meanwhile on the implementation of various software packages for the pilot project for automation of a distribution control centre.

Lastly, under a joint agreement between the Québec government and the Commission of European Communities, Hydro-Québec and a German firm will soon begin to study the technical feasibility of producing hydrogen in Québec and shipping it to Europe.



MARKETING

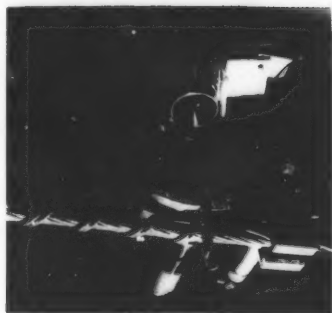
Several agreements were signed in 1988 with companies wishing to market products developed by Hydro-Québec. One involves the creation of Strateck Technologies International, a joint venture with the Montreal firm Roy, Bourassa et Associés, aimed at marketing new MECO (Mainframe External Control of Operations) software developed by the *Vice-présidence Informatique* (Computer Services) for central computers.

In addition, two agreements were signed with ASEA Brown Boveri, one for the manufacture and marketing of an automatic device for recording transients, the other for testing HV apparatus in Hydro-Québec's laboratories. The latter, a three-year agreement, is worth \$4 million.

Agreements were also signed with Ferranti-Packard for the manufacture of amorphous-core transformers and with Tecrad for marketing a micro-ohmmeter developed at IREQ.

TECHNOLOGY PLANNING

The 1989-1991 Technology Plan was completed by year-end and began to be implemented throughout the utility. This plan, which defines the major orientations and main areas of Hydro-Québec's research and testing activities, is the result of consultation and dialogue among 150 experts, researchers, engineers, specialists and managers of TAI and the departments most involved.



TECHNOLOGY,

INTERNATIONAL AFFAIRS

AND IREQ

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René Leclerc
Director

**Following the
departure of
Claude Descôteaux
on March 31, 1989,
this position is
temporarily held
by Michel-André
Demers.*

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Anne Côté
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CONTROL

Manon Leclerc

Dialogue and cooperation were central to technology planning activities in 1988. Some 150 managers, experts, researchers, engineers and specialists from TAI and other administrative units of Hydro-Québec were members of the consultative committees and task forces set up by the Technology Steering Committee, under the coordination of the Direction Planification de la technologie (Technology Planning).

The objective was to draw up a three-year technology plan. The plan was approved by the Board of Directors and is already being implemented throughout the utility. The estimated budget for 1989-1991 is \$474 million.

The plan first defines three fundamental orientations for the utility's technological activities in research, development and demonstration as well as testing. These three orientations are: to serve Hydro-Québec's needs; to use technology as a tool for gradual diversification; and to develop technologies jointly with outside partners in line with government policies.

The consultative committees and task forces also defined the main areas for research and testing aimed at solving Hydro-Québec's



immediate and medium-term technological problems. These main areas are:

- Generation, where the focus will be on optimization of the design of hydroelectric facilities and on equipment maintenance, reliability and safety;
- Transmission, with the emphasis on power system simulation, reliability and optimum management of equipment;
- Distribution, where the electrical performance of the power system and underground system technologies will play a significant role;
- Utilization, covering industrial drying processes, heating devices, and electrosynthesis of chemicals.

The task forces proposed about a hundred development areas to address the utility's needs and contribute to the development of technology. The budget was established for each area, together with the division of responsibilities.

A data bank of R&D projects was established in collaboration with the various units concerned to streamline management of technological activities throughout the utility. It contains some 500 projects initiated both within TAI and in operational units of Hydro-Québec.

In addition, a study was conducted on quantifying the utility's R&D, demonstration and testing needs with a view to clarifying the objectives of technological activities, determining whether the allocation of funding is appropriate, and establishing their priorities and spinoffs.

Members of one of the task forces, formed by representatives of TAI and various administrative units of the utility, work on the integrated 1989-1991 Technology Plan.

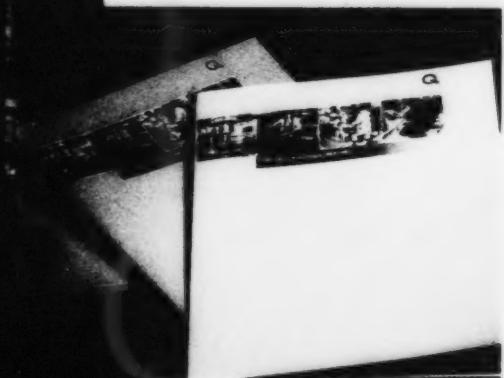
It was agreed that, starting in 1990, the units for which applied research is conducted should handle the associated budget. Implementation of this new operating mode has been simplified by developing a new way of assigning and executing R&D work between internal clients and TAI. Another objective of this method is to promote the products of R&D activities and maximize the benefits and spinoffs of technological development.

Some \$14 million has already been transferred from TAI to the other Hydro-Québec groups for the 1989 budget year, namely \$5.9 million to the *Groupe Équipement* (Installations), \$5.3 million to *Exploitation* (System Operations), \$2 million to *Exploitation régionale* (Regional Operations) and \$0.8 million to *Marchés québécois* (Québec Markets). These will mainly be used in the major applied research areas and will be added to the R&D budgets already held by the utility's operational units.

Links with various outside organizations were strengthened in 1988. Information was exchanged with the private sector and government, and R&D projects were discussed to ensure their common objectives are attained.

The *Direction Planification de la technologie* (Technology Planning) also helped coordinate TAI's involvement with various outside partners: Energy, Mines and Resources Canada, the Department of Industry, Science and Technology, the Québec government's *Commission parlementaire du travail et de l'économie* and *Ministère de l'enseignement supérieur*, several Québec universities, the Computer Research Institute of Montreal, and others.

Lastly, Hydro-Québec, with Ontario Hydro, Bell Canada Enterprises, Electrical and Electronic Manufacturers of Canada, the National Research Council Canada and the Department of Industry, Science and Technology, contributed to the creation of a Canadian Automated Building Association, which will work in the area of intelligent buildings.



Generation-related activities in 1988 included the development of several measuring, control, monitoring and maintenance systems for turbine-generators. The universal relay for generator protection (RUPA), for example, was installed and subjected to field tests. On the other hand, SUPER, a continuous monitoring system for turbine-generators, has been in operation for several months in a power plant; further work on this project will focus on the development of diagnostic tools. Among other activities this year, mention should be made of the design of capacitive transducers for measuring the vibration of stator windings and a study of partial discharges in the insulation of rotating machines.

In the area of maintenance, the compact robot designed for repairing damage due to cavitation successfully underwent its first field tests in a generating station. Meanwhile, final touches were put to the third version of the production planning model, NUMA, before it was implemented. A study of operating problems at Gentilly 2 nuclear power station was conducted and further work undertaken on wind turbine diesel-generator systems.

DEMONSTRATION OF THE RUPA RELAY

A universal relay for generator protection (RUPA) was demonstrated at Carillon generating station in cooperation with the *Direction Équipement de production* (Generating Equipment).

Using microprocessors for generator protection allows substantial space savings as well as offering incomparable flexibility, since improved protection strategies can be implemented quite easily by updating the application software. This should lead to greater reliability of protection equipment and



shorter verification, maintenance and repair times. The new relay is compatible with Hydro-Québec's computerized generating-station control system, which will ensure greater uniformity of protection systems throughout the area served by the utility.

According to Hydro-Québec's construction program, by 1992 RUPA relays will be installed on 96 generators at nine generating stations, including two entirely new plants.

Électronique (Electronics)

PROJECT SUPER

Phase II of project SUPER, a continuous monitoring system for turbine-generator units, got underway in 1988. This second phase involves developing an intelligent diagnostic tool based on the computer program that processes and analyses the data provided by the SUPER transducers.

These transducers measure more than 50 of the most representative parameters of the status of a turbine-generator unit: vibration, temperature, pressure, flow rate, voltage, current, etc. All the data are processed by a microcomputer which uses them to plot trends, enabling decision-makers to monitor station equipment more efficiently and to take prompt action.

The SUPER system has been operating for nine months at Rapide Blanc generating station in the Mauricie region and has proved entirely satisfactory. The utility plans to install 16 industrial prototypes of this system in 1989.

Mécanique (Mechanical Engineering)

VIBRATION MEASUREMENT ON STATOR WINDINGS

A new family of capacitive transducers has been developed by a research team in collaboration with the *Direction Appareillage* (Apparatus) for measuring the vibration of stator windings of large generating units. The measurement data will allow engineers to assess the degree of deterioration of the winding insulation so that they can better schedule maintenance and avoid forced outages due to equipment failure.

The results of preliminary tests with experimental transducers installed on generators in the Manic-Outardes region showed that the vibrations, on the order of 20 μm , can be measured with great precision. Since then, the research team has designed a measuring device for taking periodic readings of vibrations. This device should be available to generating-station maintenance personnel in 1989. The new transducers are based on those developed for the dynamic air-gap measuring system. The latter technology has just been transferred to Nouveler's subsidiary Vibro-Meter, which now has all the technical data it needs to manufacture and market this product and even make any modifications or adjustments it deems necessary.

Électronique (Electronics)



A universal relay for generator protection (RUPA) is demonstrated at Carillon generating station.

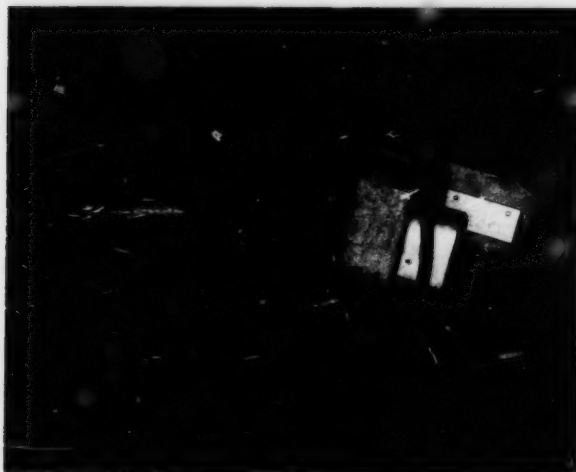
FIELD TESTS ON A ROBOTIZED TURBINE-REPAIR SYSTEM

The robotized turbine repair system passed its first tests with flying colors. In November 1988, the compact robot was installed between two blades of a Francis turbine 5.4 m in diameter. It successfully gouged the area damaged by cavitation, welded inside the cavity and then ground the excess weld material. The site selected for these tests was Wells generating station near Sault Ste. Marie, Ontario.

It can thus be concluded that the grounding and grinding processes have now been thoroughly tried and tested. The robot has a duty cycle of over 90%, which is far higher than what can be expected when the work is done manually. In the coming months, an adaptive control technique will be developed so as to obtain comparable efficiency for the welding process. A second experiment is scheduled for June 1989 on a Kaplan turbine at Carillon generating station.

The development of this compact robot is the result of a joint project launched in 1985 by Hydro-Québec and Ontario Hydro Research Division.

Technologie des matériaux (Materials Technology)



IRECA-HYDROLOY WELDING ELECTRODES

A quality-control procedure has been established for new welding electrodes made from IRECA steel, which Stoodly Deloro Stellite began to market under the name Hydroloy HQ 913 in 1988. The new procedure involves chemical analysis of the materials together with weldability, ductility and erosive-cavitation resistance tests on the welding wire and electrodes.

The results of laboratory studies and tests in generating stations show that Hydroloy wire offers a combination of the essential properties – weldability, ductility and erosion resistance – far superior to that of any other product on the market. The influence of various elements in the chemical composition of the wire was also investigated. Hydro-Québec plans to promote the use of this new steel in castings that must have optimum resistance to erosive cavitation.

Technologie des matériaux (Materials Technology)

OPTIMUM GENERATION PLANNING

As soon as the third version of the generation planning model NUMA was completed, it was implemented for the *Direction Conduite du réseau* (Power System Operations) for weekly planning purposes. NUMA allows several aspects of generation planning to be considered at the same time: for example, run-off, power transmission and energy exchanges with neighboring systems. To resolve the large-scale generation optimization problem, a nonlinear programming technique was developed, which has proven both robust and effective in minimizing convergence time.

Implementation of NUMA, the first such tool developed for weekly optimum planning, marks a further step towards the ultimate goal to build up a set of generation-optimization models – for multi-year to real-time applications. The need for such a tool is becoming increasingly urgent at Hydro-Québec.

Méthodes numériques (Numerical Methods)

The prototype of the robotized turbine-repair system, developed in collaboration with Ontario Hydro, passes its first tests in a generating station.

INTERPRETATION OF DISCHARGE SPECTRA

Recent work on the aging of stator windings in rotating machinery has focused on a study of the degradation of epoxy exposed to partial discharges. The ultimate aim of this project, undertaken for the *Direction Appareillage* (Apparatus), is to establish the maximum permissible intensity level for discharges that occur during the operation of rotating machines. This will involve a new program in 1989 to develop techniques for measuring and interpreting the spectra of these partial discharges in generators in operation.

In addition, work continued on fundamental research for the Canadian Electrical Association on the nature and mechanisms of discharges in epoxy-insulated apparatus.

Câbles et Isolants (Cables and Electrical Insulation)

EMERGENCY POWER-SUPPLY RESTORATION OF AUXILIARY SERVICES AT GENTILLY 2

The stability study program ST600 developed in-house was used to simulate all the scenarios for restoring the auxiliary services at Gentilly 2 nuclear power station, from the main grid, following a province-wide failure.

The studies were conducted by Gentilly 2 engineers with assistance from the research team. They revealed that anomalies had occurred which had an immediate impact on the overall strategy governing the emergency power supply for auxiliary services at the nuclear plant. Research will continue in the quest for a long-term solution to this problem.

Meanwhile, work is underway on a joint project aimed at developing a detailed digital model of the generating station, including the reactor, with a view to increasing simulation accuracy.

Méthodes numériques (Numerical Methods)

THERMAL STABILITY OF MORPHOLINE

A series of laboratory measurements using a pressurized-water reactor was performed on morpholine, which is used as a pH agent in the steam-water cycle at Gentilly 2 nuclear generating station to inhibit corrosion. The aims of this study were to evaluate morpholine's thermal stability under station operating conditions, to identify its degradation products and to propose a decomposition mechanism.

The study yielded the data needed to determine the decomposition kinetics of morpholine (reaction rate, half-life, activation energy, etc.) and to confirm the formation of volatile amines and other organic acids. Work is now underway to determine the amounts of such substances in the Gentilly 2 cycle as a first step towards an evaluation of their corrosive potential. The findings to date have altered the station operators' interpretation of the cation conductivity parameter.

This research is part of a joint project with electrical insulation specialists at IREQ.

Chimie des matériaux (Materials Chemistry)

WIND TURBINE-DIESEL GENERATOR SYSTEMS

Planning has begun for *in situ* tests on a wind turbine-diesel generating station intended for networks in the isolated Northern Québec region of Ungava that are not connected to the main electrical grid. The plant would comprise three 120-kW wind turbines, which should be able to meet the peak demand of approximately 360 kW of the Ungava community for which it is intended. Work has begun on automating the controls of the existing diesel generating station. The next step will be to

design and install a control system for the wind turbine-diesel generator coupling, followed by 12 months of measurements and adjustments.

The decision to proceed with these tests was prompted by the results of economic-viability studies which had shown that the operating deficit in Northern Québec could be reduced by combining wind turbines with existing diesel generating units. The most economical scenario will result in an installed wind power capacity equal to or even greater than the peak demand. When winds are strong enough, the diesel units would be shut down and the wind turbines could meet demand alone.

An earlier pilot project at Kuujuaq had demonstrated the technical feasibility of a wind-diesel tandem installed in Northern Québec and the reliability of this type of equipment. Research is now underway to define a control and regulation system that will allow a high level of penetration.

Potential annual savings in Ungava amount to \$4.4 million. Fuel savings would not only cover the investment but also reduce the operating deficit by \$1.6 million. Shutdown of the diesel units for one third of the time will save \$1.2 million on maintenance as well as trimming investment costs by \$0.2 million. Accelerated depreciation achieved by leasing could result in a further reduction of \$1.4 million in investment costs.

Mécanique (Mechanical Engineering)

Power transmission was the focus of a wide range of studies in 1988. First, a test program was established for the EHV cables to be used for the St. Lawrence under-river crossing and simulation studies were conducted to examine the system design criteria, interconnections and energy imports. Then, in the area of electrical insulation, studies were conducted on SF₆ and other insulating gases, on transformer oil degradation, on dissolved-hydrogen-in-oil levels and on the mechanical resistance of transformer tanks. The performance of wall bushings and HVDC cable terminations was also investigated.

Various measuring and diagnostic systems were developed during the year. Thus a new lightning-current measuring system was tested, installation of the central unit of the phase-angle measuring system was completed, and two new measuring units were built. In addition, an expert system was developed for the diagnosis of electrical apparatus.

The biological effects of electric and magnetic fields gave rise to two new projects. Other subjects investigated include the effects of acid rain on power system equipment, electromagnetic interference, fracture mechanics, ground electrodes, low-sag bundled conductors and single-phase reclosing. Lastly, multiple tests were performed on different types of equipment in the high-voltage and high-power laboratories.

EHV CABLE TESTING

The finishing touches were put to the EHV test and demonstration program for the 500-kV DC cables to run beneath the St. Lawrence River between Grondines and Lotbinière. The program is thus ready for the new underground-cable test facilities that the high-voltage laboratory will put into service in a few months (see "New Facilities", page 47).

A considerable effort was devoted to developing software for studying the thermal behavior of the under-river crossing and designing the cable ducts and instrumentation for the cable test station. In addition, a set of computer programs was developed for analysis of the safe loading level for the transmission cables (see "Test Techniques and Measuring Devices", page 39).



In order to study the mechanical behavior of 500-kV DC cables buried in ducts, the research team performed short-circuit tests to simulate some of the most severe conditions to which the cables of the Grondines-Lothbinière crossing may be subjected. These tests provided important data for the type tests to be performed in 1989 on the 500-kV DC cable prototypes to be supplied for testing.

Meanwhile, work continued on the preliminary studies of future 735-kV AC river crossings. The findings provided the basis for establishing the technical specifications for oil-insulated cables and SF₆-insulated buses. In addition, the first bids submitted by manufacturers were analysed and test protocols drawn up. Early in 1989,

the research team will begin to formulate recommendations for programs to demonstrate the long-term reliability of these technologies under real river-crossing conditions.

Câbles et Isolants (Cables and Electrical Insulation)

ENERGY IMPORTS VIA CHÂTEAUGUAY SUBSTATION

Studies continued throughout 1988 on the possibility of using Châteauguay substation for importing energy during peaks on the Hydro-Québec system. The research involved modeling the two converters, the AC filters and the static compensators as well as the equipment at Beauharnois generating station and the Hydro-Québec and New York Power Authority grids.

A technician from the Japanese firm Hitachi completes preparations for a 500-kV cable junction that will be tested at the high-voltage laboratory. Tests on prototypes from Hitachi,

The results of these studies prove that Hydro-Québec can safely import energy from the U.S. and/or repatriate it from the Beauharnois isolated generating station via Châteauguay to meet the peak demands on its power system. The study also confirmed the stable operation of the Châteauguay converter station when second-harmonic filters are operating.

Études de réseaux (Power System Studies)

REVISION OF THE TRANSMISSION SYSTEM DESIGN CRITERIA

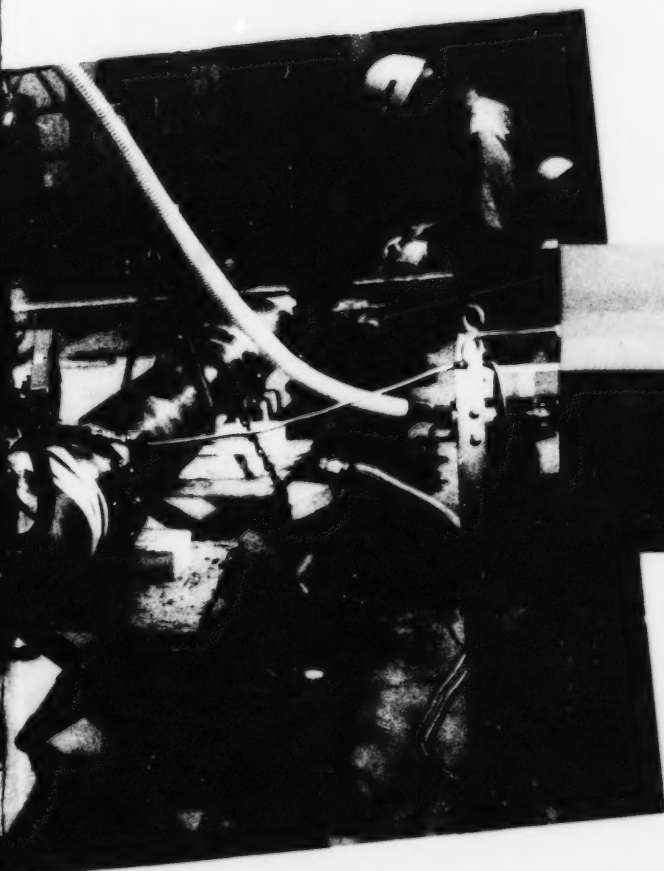
An AC power system simulator study was conducted as part of the current revision of Hydro-Québec's transmission system criteria. The first task was to establish the constraints to which the new series compensators and line circuit-breakers will be exposed.

The researchers evaluated the energy dissipated in the varistors protecting series-capacitor banks on the Manicouagan-Lévis-Saguenay network when various types of fault are applied to the lines; the measurements were made for several possible system configurations. This study determined the operating limit for the energy counters that trigger the spark gaps used for switching the series compensators.

The results obtained allowed the Groupe Équipement (Installations) to establish a precise definition of the general electrical characteristics to be respected by manufacturers of series compensation equipment. They intend to pursue these studies in 1989 on the James Bay and Churchill-Manicouagan networks.

Études de réseaux (Power System Studies)

STK of Norway and Pirelli of Italy will help to determine the cables to be used for the St. Lawrence under-river crossing between Grondines and Lothbinière.



RESEARCH ON INSULATING OILS

A research project on commercial insulating oils was initiated in 1988. Aimed at identifying the causes for the degradation of oils used in PP-type Merlin-Gerin air-blast circuit breakers, the project consists in comparing the oxidation resistance of different oils as a basis for recommending the best one available on the market.

Meanwhile, an analysis was performed of not only the results but also the process parameters adopted by the Hydro-Québec maintenance and repair centre in Varennes for recovery of more than 500 000 litres of Voltesso 35 transformer oil. A research project will be proposed in 1989 with a view to optimizing this recovery process.

Two methods have been developed for sampling and homogenizing oil to be used for laboratory analysis. This should ensure oil samples removed from in-service equipment are more representative and thereby increase the relevance of the analyses.

A seminar on cable and transformer oils was organized in February 1988 for technical personnel from all Hydro-Québec's administrative regions to promote technological transfer of the last few years' research in this field.

Câbles et Isolants (Cables and Electrical Insulation)

MECHANICAL RESISTANCE OF TRANSFORMER TANKS

A study has been initiated to establish standards for the mechanical performance of 735-kV transformer tanks subjected to an explosive internal fault. In fact, power transformers can experience internal breakdowns so powerful that the tank is often shattered, spilling substantial quantities of oil and creating a serious risk of fire.

Undertaken in collaboration with the *Service Études et Normalisation* (Studies and Standardization), the project has a threefold objective: modeling, digital simulation, and experimentation with scale models. The research team has already prepared a test set-up for reproducing faults, defined the required models and developed simulation software.

This study represents the first step in a new avenue of research that should gradually expand to include other types of electrical apparatus.

Mécanique (Mechanical Engineering)

PERFORMANCE OF GAS INSULATION

Work began on establishing the requirements for SF₆ or SF₆/N₂ insulation systems under the operating conditions of circuit breakers. The project focuses on the short- and long-term factors affecting such insulating systems, and involves conducting various physicochemical, optical and electrical analyses on these insulating gases.

One of the tools required for this study is chromatographic analysis. A new procedure developed in-house for the purpose of the project will be used primarily to assess the quality of the SF₆ and rapidly

determine the concentration of major impurities (air, moisture, decomposition products). It will also serve, however, to evaluate the quality of the SF₆ used for almost ten years now in Hydro-Québec's three gas-insulated substations.

Câbles et Isolants (Cables and Electrical Insulation)

HVDC WALL BUSHINGS AND CABLE TERMINATIONS

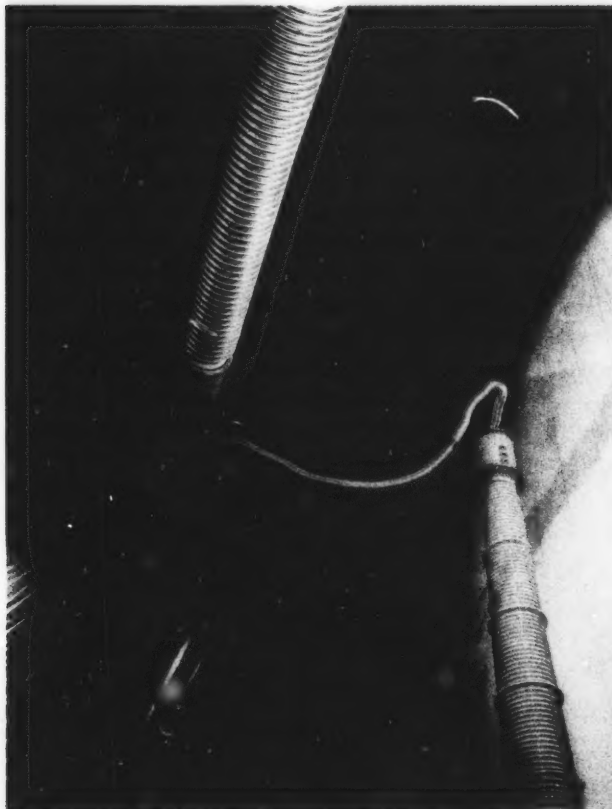
Apart from substations such as Châteauguay, where the rectifier and inverter are indoors and directly connected, HVDC substations generally comprise horizontal wall bushings, tilted at an angle of 15°, which connect the outdoor converters to the equipment inside. Electrical utilities around the world have found that the HVDC wall bushing is the weak link in the power transmission chain. Three problems have been identified: puncture of the bushing under the effects of rain or fog; flashover due to nonuniform wetting with little or no contamination; and external flashover caused by a higher contamination rate on the insulators where the unidirectional electric field attracts particles of the contaminant.

In April 1988, researchers submitted to the *Vice-présidence Ingénierie et Construction* (Engineering and Construction) a project aimed at improving the performance of wall bushings and determining the performance of HVDC cable terminations exposed to rain with a low contamination level. The proposal was accepted and specifications were drafted for the purchase of a wall bushing for laboratory testing. Delivery is scheduled for fall 1989.

Meanwhile, a study is underway on voltage distribution in cable terminations and wall bushings, and on the flashover mechanisms of electric arcs occurring on the surface of this equipment. Tests on scale models are planned for 1989.

Lignes aériennes (Overhead Lines)

HVDC wall bushings are tested in pollution chambers at the high-voltage laboratory to determine their characteristics and improve their performance.



LIGHTNING-CURRENT MEASURING SYSTEM

The 735-kV line 7009 spanning the St. Lawrence River less than 5 km from the IREQ laboratories was the first site selected for measuring lightning currents with new instrumentation developed for the *Direction Appareillage* (Apparatus), Hydro-Québec. Each system comprises a single transducer in the form of a coil inserted round the base of a tall tower (85 m) and a battery-operated digital data acquisition unit housed in a weather-proof box. Three of these measuring systems were installed on line 7009 during the year, and two others were tested on an experimental line at IREQ in Varennes.

Meanwhile, a visit was organized to NASA's rocket-triggered lightning research facility at the Kennedy Space Center in Florida. In summer 1989, it is planned to test two of the new systems at the NASA centre using artificially produced lightning.

Lignes aériennes (Overhead Lines)

BIOLOGICAL EFFECTS OF ELECTRIC AND MAGNETIC FIELDS

The priority in 1988 was given to initiating projects in Hydro-Québec's action plan on the effects of electric and magnetic fields. Work also continued or resumed on projects already underway and marked significant progress.

Two projects were launched during the year, one on human perception of ion currents and fields produced by DC lines, the other on the characterization of electric and magnetic fields in the environment.

Meanwhile, work continued on the dosimetry aspect of an epidemiological study conducted jointly by Hydro-Québec, Ontario Hydro and *Électricité de France* on the incidence of cancers related to exposure to electric and magnetic fields. The activities this year consisted mainly in developing the software needed for operating the dosimeters built first by Hydro-Québec and then by Positron Industries Inc.

In addition, an exposure chamber was completed for a study conducted jointly with the *Institut de cancer de Montréal* on the effects of magnetic fields on living cells.

Joint funding from the Canadian Electrical Association and the Electric Power Research Institute in the United States made it possible to resume a study on electrical burns. The group's contribution is related to the instrumentation and data acquisition system.

Environmental monitoring of the 450-kV DC bipolar interconnection entered its final phase in 1988. The measurements should be completed by next spring and will be followed by an exhaustive analysis of the data collected.

Lignes aériennes (Overhead Lines)

PHASE-ANGLE MEASURING SYSTEM

Marked progress was made in 1988 on the phase-angle measuring system, now in its third version. The main purpose of this development is to provide an overall view of the 735-kV power network so as to locate the incidents that occur with respect to the main transmission lines, identify the type of incident (fault, tripped line, generation or load loss, etc.) and swiftly assess their significance.

The measuring system comprises four permanent measuring points located at Boucherville, Château-guay and Arnaud substations and La Grande 2 generating station. The peak voltages and voltage zero-crossing times are sent at each cycle to the central unit, which compiles the signals, performs a real-time analysis and records all disturbances that exceed predetermined limit values.

The user can access the data via a microcomputer or a graphic terminal and obtain curves of the voltage, frequency, phase angle and other parameters. The data can also be transferred in digital form to the user's computer.

The activities in the last 12 months include installation of the central unit at the System Control Centre in Montreal and the production of two additional measuring units for the *Service Essais et Expertises Techniques* (Testing and Technical Appraisals). In addition, final touches were put to the acquisition software, while the first data processing software intended for users went into service.

Électronique (Electronics)

EXPERT SYSTEM FOR TRANSFORMER DIAGNOSTICS

Development of the prototype expert system SEDA-TRANSFO this year provided an opportunity to validate the concept underlying the expert system for diagnosis of electrical apparatus, SEDA as it is known in-house, by applying the technology to power transformers in an automatic-tripping situation.

The purpose of this development, which is just one aspect of a far-reaching project on expert systems at Hydro-Québec, is to establish an approach for setting up an entire family of cooperating expert

systems covering all the apparatus of a given installation, a substation for example. SEDA consists of two basic elements. The first, SEDA-G, is designed to gather and process the computerized data for the entire installation. The second comprises SEDA-PX, PY and PZ, which are expert systems for diagnoses of individual items of switchgear. The demonstration prototype is the first SEDA-PX designed in this context.

The work was carried out in conjunction with the *Service Essais et Expertises* (Testing and Technical Appraisals) and the *Direction Appareillage* (Apparatus).

Électronique (Electronics)

CIRCUIT-BREAKER TESTING

The high-power laboratory performed many tests in 1988, mainly on circuit breakers. For example, tests with the fault applied at the terminals as well as short-line-fault tests were performed on an SF₆ circuit breaker module at 735 kV. This module was installed in an insulating enclosure and the temperature was lowered to -50°C. The transient recovery voltage, in conformity with IEC standard 56, was obtained by means of IREQ's synthetic test circuit. The enclosure can be adjusted to the size of the test object and it is easy to dismantle when not in use. The cooling device, consisting of two compressors, is mobile and can therefore be used in any of the laboratory test cells.

The laboratory personnel also performed measurements of the impact noise of a 735-kV air-blast circuit breaker equipped with a silencer. The purpose of these tests, which were conducted during short-circuit current breaking, was to assess the possibility of reducing the noise level to less than 140 dB without affecting the unit's breaking capacity.

Hundreds of capacitive current making and breaking tests (up to 180 A at 173 kV) were also performed on one chamber of a single-pole module of an 800-kV SF₆ circuit breaker.

The planned under-river crossing has already occasioned mechanical resistance tests on ducts containing HV cables intentionally punctured by a wire so as to produce an electric arc. The objective was to validate safety aspects of ± 450 -kV DC and 735-kV AC underground cables.

Other testing activities in 1988 included short-circuit current withstand tests on various disconnecting switches, on a three-phase transformer and on spacers, as well as short-circuit current-breaking tests on fuse cutouts.

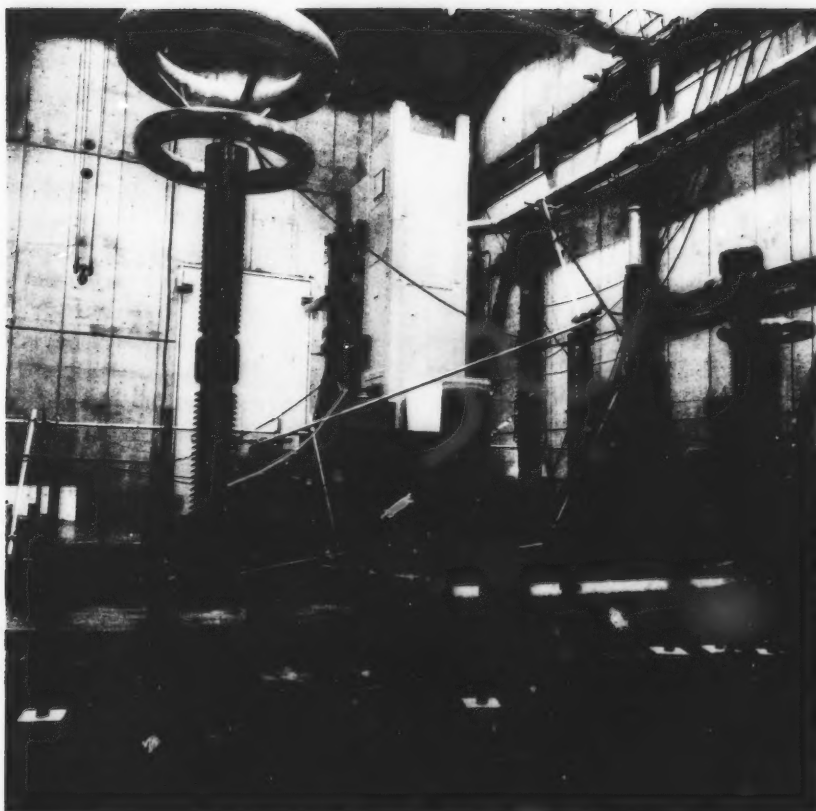
Laboratoire Grande puissance (High-Power Laboratory)

CRITICAL LEVELS FOR DISSOLVED HYDROGEN IN TRANSFORMERS

In order to determine acceptable limits for the amount of dissolved hydrogen in transformers, a statistical method was developed to compare pertinent data, gathered over the past 20 years, on healthy and defective Hydro-Québec transformers. This approach yielded far more accurate figures than the currently used distribution norms.

The study took into account the type of unit (power or instrument transformer with or without tap changers), its age and its voltage rating. In addition, critical levels were established for acetylene and ethylene, two gases indicating arcing and hot spots.

The critical levels established for dissolved hydrogen will be made available to those responsible for monitoring these types of apparatus, which will eventually be permanently equipped with hydrogen probes. As soon as the probes indicate the presence of a dangerous amount of gas, personnel can swiftly take the appropriate precautions. It should be mentioned that the new data acquisition method has aroused considerable interest outside Hydro-Québec, particularly among IEC (International Electrotechnical Commission), CIGRE (*Conférence internationale des grands réseaux électriques*) and IEEE (Institute of Electrical and Electronics Engineers) committees.



*The first
404-MVA*

HVDC converter transformers

Chemie des matériaux (Materials Chemistry)
*are tested at the
high-voltage
laboratory. These
transformers are
manufactured by
ABB of Varennes
and will be used
for the Radisson
- New England
DC line.*

EFFECT OF ACID RAIN ON POWER SYSTEM HARDWARE

A study has been performed to gain a better understanding of the potential effect of acid rain on Hydro-Québec's power system hardware.

The first stage was to analyse different items of hardware removed from substations (grounding-grid joints, bolted parts, etc.). Resistivity measurements provided an idea of their performance in the field. Although they had been in service for some 20 years, they were nevertheless in good condition. These analyses will serve as a reference for future verifications.

The second stage was to study data published by the Québec government's *Ministère de l'environnement* in order to establish an acidity profile of the precipitation throughout Québec. This analysis led to the conclusion that all Hydro-Québec substations can be affected by acid rain and that certain metallic parts are therefore subject to accelerated corrosion. The acidity decreases in intensity towards the east and northeast of the province, however.

In the final stage, it is planned to develop and install probes for measuring the corrosive effect of rain on different metals and alloys.

Chimie des matériaux (Materials Chemistry)

DUNCAN LAKE GROUND ELECTRODE

It was demonstrated that the ground electrode of Radisson substation at Duncan Lake was inducing several hundred amperes of DC current into the 735-kV transmission system, thereby causing unde-

sirable effects. This information was gleaned from simulations integrating the results of field tests, the characteristics of the rock mass and those of the transmission system.

Various means of countering the negative impact at Radisson and La Grande 2 substations were then studied. Because of scheduling constraints, however, these measures could not be applied, and the Duncan Lake site has therefore been shelved for the moment in favor of another site in James Bay that would have less effect on the 735-kV system. Pressure has now been put on completing studies underway on the possibility of installing the ground electrode in an offshore environment.

Technologie des matériaux (Materials Technology)

MECHANICAL TESTS

Two sets of tests on different types of insulator were performed in 1988. The first, on transmission line insulators, consisted of electromechanical tests at 80 kV, 60 Hz at loads ranging from 75 kN to 105 kN applied at a frequency of 0.5 Hz. The second test series was conducted on distribution line insulators and on conductor sleeves for transmission lines, to study the effects of sudden temperature changes, as well as the causes of mechanical and thermomechanical breaking.

Thermomechanical cycling tests were also performed on a 400-m length of 2750-MCM, 230-kV cable in order to study its mechanical behavior when the current raises its temperature to 90°C. A set of displacement transducers was used to record longitudinal and axial movements of the cable and displacements of the core with respect to the sheath at different temperatures.

Laboratoire Grande puissance (High-Power Laboratory)

MECHANICAL CHARACTERISTICS OF OVERHEAD LINES

Laboratory studies of the self-damping of overhead conductors have extended the range of parameters covered by existing eolian-vibration computer models. In addition, work was completed on the analysis of vibration measurements taken on the bundled conductors of Hydro-Québec's experimental line in the Magdalen Islands. The same line was used for an investigation of the aeroelastic behavior of an all-alloy three-conductor bundle.

Upon completion of the evaluation of a new double spacer-damper designed at Hydro-Québec, samples were installed on low-sag bundled conductors to study the latter's sensitivity to eolian vibrations. Subsidized by the Canadian Electrical Association, this research for Lyster Industries covers just one aspect of the Chamara hydroelectric development project underway in India.

Mécanique (Mechanical Engineering)

FRACTURE MECHANICS

A computer program now exists for describing the various stages in the development of a fault in structural components. The new software allows the typical configuration to be calibrated for a certain category of faults. On the basis of the graphic data generated, it is possible to swiftly diagnose all faults of this type.

A second project consisted in testing the four high-strength steels most commonly used at Hydro-Québec in order to study crack initiation and propagation under different conditions. A methodology combining stress and fractographic analysis was developed for rapidly determining the cause of in-service failures and applying the appropriate corrective measures.

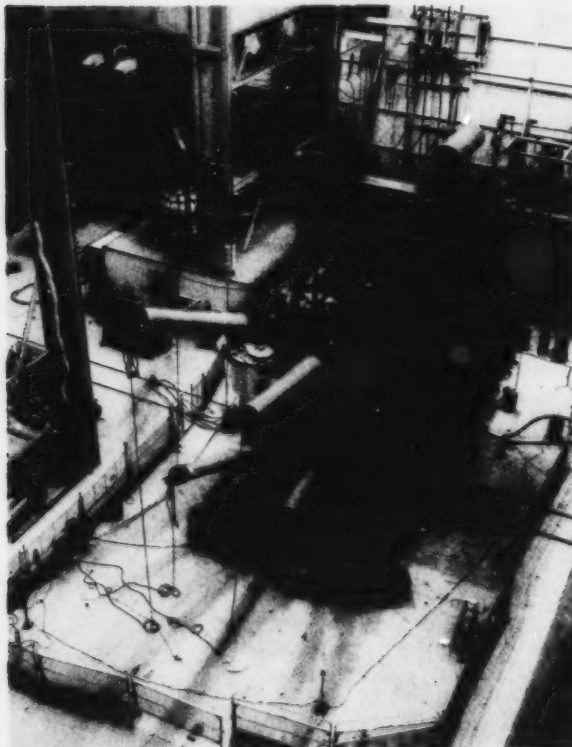
Technologie des matériaux (Materials Technology)

TESTS ON 735-kV POST INSULATORS

An experimental study was conducted to compare the electrical behavior of a 735-kV Spirelec post insulator with a conventional insulator model under conditions of rain and artificial contamination (salt fog and clean fog on contaminated elements).

The study was initiated as a result of the incidents at Arnaud substation on April 18, 1988. A heavy storm dropped large quantities of wet snow on the Spirelec insulators causing flashover and, in some cases, damage. The study revealed that the spiral sheds of these insulators have corrugated upper and lower surfaces creating an easy path for the leakage current in the presence of contamination and precipitation.

The first 404-MVA HVDC converter transformers are tested at the high-voltage laboratory. These transformers are manufactured by ABB of Varennes and will be used for the Radisson - New England DC line.



According to the results of tests conducted for the *Direction Appareillage* (Apparatus), Spirelec insulators have a better performance (5% to 7%) than conventional types in rain but show a 7% to 33% deterioration in their contamination performance.

Lignes aériennes (Overhead Lines)

CONVERTER TRANSFORMER TESTING

Laboratory tests were performed in October 1988 on the first HVDC converter transformer made in Québec for the Radisson-Des Cantons-New England interconnection project. Destined for installation at Radisson substation, this 404-MVA single-phase transformer has three windings: one $315/\sqrt{3}$ -kV HV winding and two others, 190.3 kV and $190.3/\sqrt{3}$ kV, connected to thyristor valves. The windings are designed to withstand the dielectric stresses imposed by the DC voltage.

The polarity-reversal and withstand-voltage tests included partial-discharge measurements using a counter specially designed for this purpose by the *Service Mesure et Informatique* (Measurements and Data Processing) at IREQ.

Twelve of these transformers will be built at the ASEA Brown Boveri plant in Varennes, in addition to the two prototypes manufactured at the company's plant in Ludvika, Sweden, and all will undergo similar tests in 1989-90.

Meanwhile, work on over 160 high-voltage testing contracts was undertaken for Hydro-Québec and manufacturers in 1988. This included tests on at least 30 power transformers and 60 current transformers.

Pollution tests were conducted on 500-kV HVDC bushings for the British firm, Bushing Company Ltd., and Manitoba Hydro, and a study of the behavior of this type of equipment under various pollution conditions was performed as part of a project sponsored by the Canadian Electrical Association. Lastly, a large number of tests were conducted in a study of the behavior of a 450-kV bipolar DC line exposed to fire.

Laboratoire Haute tension (High-Voltage Laboratory)

NEW CRITERIA FOR LOW-TEMPERATURE SIMULATION OF SF₆ CIRCUIT BREAKERS

Research related to the development of new SF₆ circuit breakers for operation at -50°C raised questions about the use of criteria for testing at 20°C when simulating operating conditions at extremely low temperatures. Preliminary results of this investigation show that gas pressure is the most important parameter to consider, rather than gas density, which is the criterion currently accepted in the standards.

In order to clarify the relative importance of these parameters, the *Service Études et Normalisation* (Studies and Standardization) requested a research program. The aim of this research is to define criteria for testing at 20°C that could be used for simulating conditions at -50°C.

Interrupting tests were conducted this year on a first circuit breaker under various temperature, gas pressure and gas density conditions. Other tests are planned, this time on a puffer circuit breaker of another design to make sure the equivalence holds for all equipment of this type. A newly developed post-arc modeling technique will increase the confidence level of the criteria selected.

The new 20°C test criteria established in this research program will soon be incorporated into Hydro-Québec's own technical specifications and, possibly, into international standards.

Appareillage électrique (Electrical Apparatus)

CALCULATION OF ELECTROMAGNETIC INTERFERENCE

In order to gather basic data on electromagnetic interference, especially in HVDC environments, a program of field measurements was undertaken by TAI, the *Service Essais et Expertises techniques* (Testing and Technical Appraisals) and Bell Canada with the following objectives:

- to validate existing methods (and the results) of calculating the different types of coupling between a transmission line and telephone lines
- to measure the harmonics generated by the Des Cantons converter station under a wide range of operating conditions
- to establish the characteristics of a typical telephone line.

Two sites were selected, one at Des Cantons to study harmonics at the source and the other in an isolated area to study the couplings. The measuring instrumentation at the second site consisted of current transducers installed on all the conductors of the HVDC line and, together with a number of voltage transducers, on two typical Bell Canada circuits. The voltage measurements were subsequently used to calculate the couplings in terms of the position and geometry of the conductors comprising the telephone circuits with respect to a reference power line.

Special attention was given to the design of the current transducers, which had to meet stringent requirements. In addition to detecting weak harmonics in the presence of strong charging currents, they had to possess an excellent response in the frequency band under consideration. Since they were required to have signal insulation for 450 kV DC, they had to be self-powered (by means of solar batteries). Lastly, they were to be designed for installation on a conductor bundle without interrupting the current.

The field data from the two sites will improve the accuracy of the protection coordination calculations performed by the *Vice-présidence Planification des équipements* (Power System Planning), which requested this study. Hydro-Québec will thus be able to reduce the costs associated with higher than necessary safety margins and the preventive measures applied to preserve service quality. Furthermore, it will avoid inconvenience to telephone subscribers, who are also, of course, customers of Hydro-Québec.

Appareillage électrique (Electrical Apparatus)

SINGLE-PHASE RECLOSING AT 315 kV

When one phase of a high-voltage line opens, the power arc is extinguished but a low-current secondary arc persists for a short period of time. Its source is the capacitive coupling between the open phase and the two phases that are still energized. This secondary arc maintains the conductivity of the and imposes a delay on single-phase reclosing of the line in order to avoid a consecutive short circuit.

Laboratory measurements of the secondary-arc extinction time were performed to determine the minimum time delay needed for safe single-phase reclosure of 315-kV lines. This delay is the sum of two time intervals. The first equals the duration of the secondary arc itself, while the second is needed for recovery of the insulating strength of the air following extinction of the secondary arc.

Tests have revealed that a time delay of 1.3 s is sufficient for 90% success in single-phase reclosing for a secondary arc of 40 A and a recovery voltage of 40 kV (non-transposed 315-kV double-circuit line); for a 20-A current, the time would be 0.8 s.

The determining parameter for secondary-arc extinction is wind speed. When there is no wind, the secondary arc can last several seconds; however, even a slight breeze will reduce the time to less than 1 s under similar conditions. In the total absence of wind, a number of unsuccessful single-phase reclosings can therefore be expected. In such cases, conventional three-phase reclosing will be used. The project will continue with shunt reactors included on certain lines, since this type of apparatus also affects the phenomenon under study.

Appareillage électrique (Electrical Apparatus)

LOAD BEHAVIOR MODELING

A new measurement system for modeling the various components of the Hydro-Québec network has been developed for simulation and control purposes. The system requires less human intervention, is expected to be more reliable and thus should be more cost-effective than existing systems. In addition, it can gather a larger variety of data required for sophisticated modeling of loads and other components of the network.

The system consists of a central computer (IBM PC or equivalent) controlling several substation-resident portable units via a nondedicated telephone line. The frequency, voltage and power variations, during natural as well as staged perturbations, will be automatically saved and transmitted to the central computer. The first unit, now being installed, will gather data pertinent to load modeling.

Méthodes numériques (Numerical Methods)

MODELING OF STATIC VAR COMPENSATORS

Two original models of a static var compensator (SVC) have been developed and implemented into the ElectroMagnetic Transient Program (EMTP). A separate initialization procedure speeds up reaching steady-state conditions.

The three-phase SVC with thyristor-controlled reactors and fixed capacitors lends itself well to modular representation. This advantage will allow the models to be adapted for other types of static compensator and make them easier to use on large networks.

The new SVC models have been made available to Hydro-Québec's system planning engineers, who have already applied them in their review of the utility's transmission system design criteria.

Méthodes numériques (Numerical Methods)

The primary concern in all distribution-related activities in 1988 was the quality of customer service. This concern led to the development of a second generation of the terminal units to be used for the supervisory-control system at the distribution level. It was also reflected in the studies of three-phase voltage unbalance and nuisance fuse operation during magnetic storms. A patent has been obtained for a current-limiting fuse which uses a ceramic arc-extinguishing medium.

Other work included studies of extruded-cable aging, composite insulators and joints, together with an investigation of combustible gases in manholes and underground vaults. A new voltage detector has called for a revision of the related standards. Meanwhile, development work on power system planning software was completed. Lastly, an important series of tests on single-phase separable connectors was performed in the high-power laboratory.

SECOND-GENERATION SUPERVISORY-CONTROL SYSTEM

The success of the supervisory-control pilot project on the distribution network in St-Jérôme prompted the research team to develop a second generation of terminal units to meet the specific requirements of Hydro-Québec's distribution specialists. Over 80 units were manufactured by Les Contrôles PSC in 1988.



The units will be installed on the 25-kV distribution network in the Richelieu and St-Laurent regions to reduce the duration of interruptions and thus improve service quality.

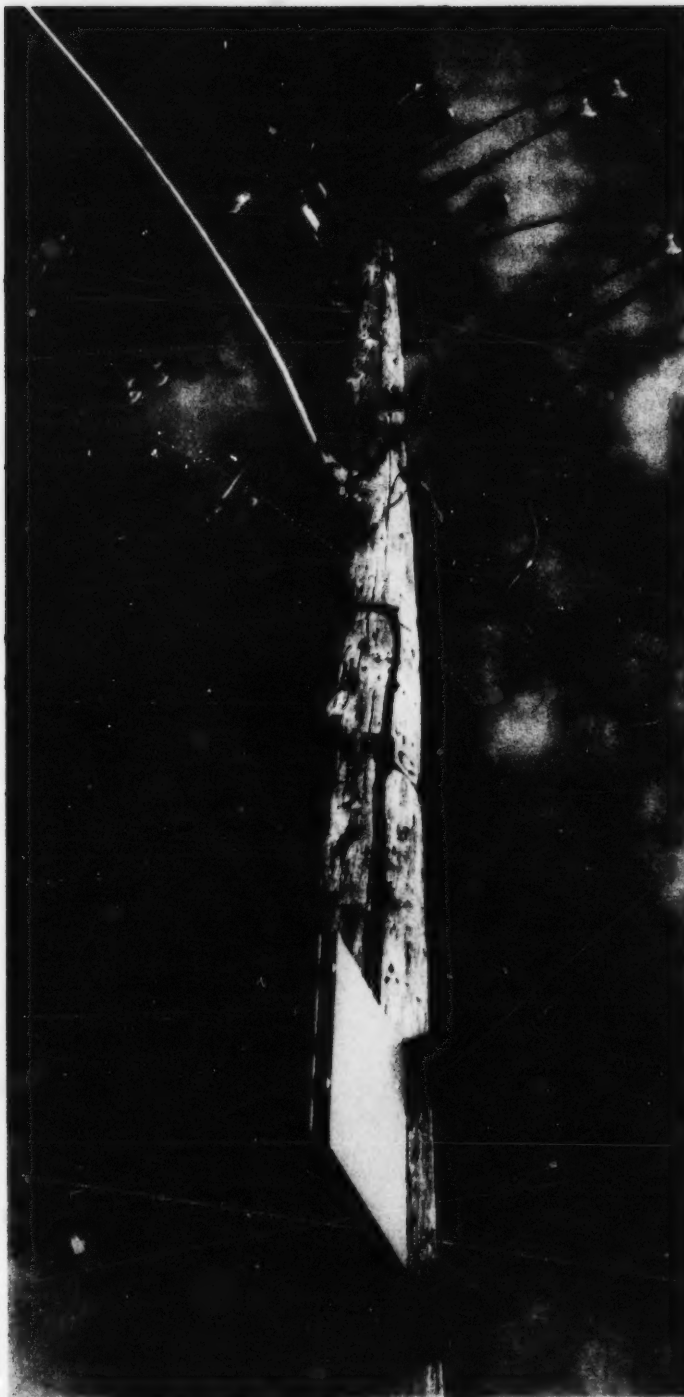
The new terminal unit consumes very little energy and is specially designed to operate at very low temperatures in environments exposed to strong electromagnetic interference. It has a flexible mode of communication, which uses radio or telephone cables. Discussions have begun with a manufacturer to explore the interesting international market potential of this product.

Electronique (Electronics)

THREE-PHASE VOLTAGE UNBALANCE

In a study for the Canadian Electrical Association and Hydro-Québec, some 50 million voltage measurements were performed and processed to evaluate the typical voltage unbalance on six Canadian distribution networks. The test campaign and the sample-processing technique are both firsts in North America.

A researcher checks a second-generation terminal unit used for supervisory control of the distribution network. More than 80 of these devices have been manufactured and will be installed in two Hydro-Québec regions to improve customer service.



Prior to this project, electrical utilities were dependent on NEMA (National Electrical Manufacturers Association) standard MG1-1978. This standard is used as a reference by industrial customers demanding compensation for motors damaged by voltage unbalance. The results of the project shed new light on claims that unbalance leads to accelerated aging of motors: they show clearly that NEMA's recommended safety margin is excessively demanding on Canadian distribution networks. This margin can be explained, however, by the inaccuracy of the measuring and analysis methods used.

The new approach offers far greater accuracy in the evaluation of distribution voltage unbalance. It also offers utilities a chance to propose amendments to the NEMA standard to make it less demanding, while at the same time respecting the characteristics of existing motors in order to avoid deleterious effects.

Appareillage électrique (Electrical Apparatus)

NEW CURRENT-LIMITING FUSE DESIGN

The group has designed a new type of current-limiting fuse that uses a ceramic as the extinguishing medium rather than the quartz sand found in conventional fuses.

This innovation has radically improved fuse performance and limits the energy dissipated by a fault to one-third the value predicted for conventional fuse designs. A prototype has now been built in order to confirm the laboratory results. The role of the new fuse will be primarily to protect power electronic devices such as thyristors, which cannot withstand excessively high temperatures. Research is now underway in an attempt to lower production costs, and discussions have begun with industrial partners.

The fuse was patented in the United States in August 1988.

Appareillage électrique (Electrical Apparatus)

AGING TESTS ON COMPOSITE INSULATORS

Six types of composite insulator commonly used on Hydro-Québec's distribution system were subjected to accelerated-aging tests to study the effects of voltage and pollution. The influence of solar radiation on aging was also evaluated. The main purpose of the tests was to ensure that these insulators meet in-service requirements and, also, to validate the IEC (International Electrochemical Commission) and IEEE (Institute of Electrical and Electronics Engineers) aging-test methods.

Two of the insulators had demonstrated certain weaknesses in service and again showed a relatively poor performance during the modified diagnostic tests performed to evaluate laboratory aging. Yet according to the recommended IEC salt-fog test and IEEE tracking-wheel test, all insulators met the standard prescriptions! The acceptance criteria for the accelerated-aging methods were consequently revised in order to be able to distinguish between insulators of different quality. The new criteria could be proposed to the two standards organizations for approval.

Lignes aériennes (Overhead Lines)

NUISANCE FUSE OPERATION ON DISTRIBUTION TRANSFORMERS

Many fuses protecting pole-mounted distribution transformers blow during storms for no apparent reason: the transformers protected show no sign of having sustained a fault. This causes nuisance service interruptions after thunderstorms and requires intervention by linemen. As the phenomenon has never been explained, the Canadian Electrical Association and Hydro-Québec turned to the group for a study and tests aimed at determining the event or sequence of events responsible, the equipment involved and the relative importance of each factor.

The large capacitor bank of IREQ's synthetic circuit was used to simulate long low-amplitude, lightning-current pulses. Such pulses diverted into the transformer arrester produce a correspondingly long voltage pulse that causes saturation and a power-frequency inrush current. Although this current is naturally eliminated within 1 s, it manages to burn the fuse.

Water treeing in the polymer insulation of extruded cables is analyzed by micro Fourier transform infrared spectroscopy.

The study offers a better understanding of the various phenomena involved and proposes methods for reducing such fuse operations. Analysis of the results suggests that a realistic solution would be to exercise more care in selecting the fuse type and rating, and the arrester type and manufacturer. Fuses with a current rating above the given levels, such as expulsion types 6 K, 6 T, 15 N and current-limiting types 12 NX, 15 Q, 12 GP, do not present a problem, since they will never blow under the conditions studied in this project.

Appareillage électrique (Electrical Apparatus)



CABLES AND ACCESSORIES

Three research projects in 1988 dealt with extruded-cable aging. The aim of the first was to characterize such cables after they had been removed from service on the Hydro-Québec system. The findings so far reveal large concentrations of water and impurities in the insulation and, therefore, substantial water treeing. As a result, modifications to existing technical standards will be recommended in 1989.

The second project involved the development of a theoretical model of extruded-cable aging. The research team demonstrated that the phenomenon can be approximated by means of a two-parameter equation. Considering the number of unknowns involved, the agreement between the model and practical results is good.

The third study showed that even if oxidation does not actually initiate the formation of water trees in polyethylene, it can play a role in the final stage of insulation breakdown.

In addition, the group undertook a joint research project with the Canadian Electrical Association (CEA) to gain a better understanding of the final breakdown mechanism of extruded cables used at the distribution level.

It also conducted further work on a major program on the characterization of prefabricated splices removed from the underground network to identify the causes of in-service failures. Upon completion of its study, the research group will recommend the purchase of joints that are not only technically more sophisticated than those studied but easier to install and virtually maintenance-free.

Lastly, another project with the CEA consisted in evaluating the long-term performance of new types of splice designed to meet the requirements of ANSI/IEEE standard 404 governing cable joints for use with extruded dielectric cable for voltages of 5 kV to 48 kV. Accelerated-aging tests will be used to judge the service life of these accessories.

Câbles et Isolants (Cables and Electrical Insulation)

EXPLOSION OF GASES IN MANHOLES

Records show that gases can explode in manholes following long-duration faults on the low-voltage distribution system. In an attempt to better understand the phenomenon and curtail the associated risks, a test set-up was designed and built for determining the conditions that cause such explosions. The test results provided a clearer definition of natural ventilation in manholes and its influence on the accumulation of explosive gases. In addition, a series of tests was performed to assess the performance of the combustible-gas detectors used for maintenance work on Hydro-Québec's underground distribution system.

Câbles et Isolants (Cables and Electrical Insulation)

VOLTAGE DETECTOR

In 1988, this research team contributed to the activities of an IEC (International Electrotechnical Commission) working group responsible for defining standards for the voltage detector developed at IREQ several years ago. The operating principle of this device is based on the detection of a small resistive current flowing between the line and ground.

The team also participated in negotiations with two manufacturers of safety equipment with a view to developing and marketing the voltage detector.

Câbles et Isolants (Cables and Electrical Insulation)

TESTS ON SEPARABLE INSULATED CONNECTORS

Major tests were carried out this year on single-phase separable insulated connectors for 26.3-kV underground distribution cables. The purpose of the tests was to assess the compatibility and interchangeability of four makes of connector. By interchanging the bushings (fixed contacts) of some elements and the elbows (mobile contacts) of others, the test engineers were able to verify whether they met ANSI/IEEE standard 386-1985. More than 5000 switching tests, each consisting of ten closing/opening operations on a mainly active load of 200 A and closing on a 10-kA fault with a duration of 10 cycles, were performed for the client, Georgia Power.

Many tests were also conducted on various types of submersible switches, switchgear cabinets and fuse cutouts. Tests performed to check for conformity to ANSI standards include dielectric tests, measurement of partial discharges, interruption of mainly active load current, no-load transformer tests, no-load cable tests, closed-loop

tests, short-circuit-current withstand tests, and closing on a short circuit. Special tests comprised making and breaking tests at -40°C , tank withstand to internal arcs triggered by a fuse wire, and tests on the effect of rated 60-Hz voltage and 78 kV DC applied simultaneously between open contacts.

Among other activities in 1988, mention might be made of tests on the pressure-limiting device of metal-oxide surge arresters when the internal arc is triggered by a fuse wire and current-cycling tests on copper and aluminum connectors.

Laboratoire Grande puissance (High-Power Laboratory)

ALUMINUM-COPPER CONNECTORS

Studies of aluminum-copper connectors have pinpointed two factors likely to improve their performance significantly when they are subject to current-load cycling: preparation of contact surfaces (brushing and greasing) and the appropriate use of mechanical devices.

This work is part of an extensive research program to determine parameters that affect the deterioration of aluminum-copper connectors, upgrade their performance under various conditions (acid rain, industrial pollution and saline atmosphere), develop more precise installation methods and check their in-service reliability.

Technologie des matériaux (Materials Technology)

DISTRIBUTION SYSTEM PLANNING

New planning software is now being tested in the Laurentides, Montmorency and St-Laurent regions. It was developed in the framework of a distribution system planning project to help planners select equipment for expanding or upgrading the system in their sector.

The new software can predict overload and voltage-drop problems several years in advance. It can also automatically establish and subsequently analyse various system configurations for a given year on the basis of switching points selected by the planner.

Testing began in the fall and will be completed in May 1989. The software will be available to all Hydro-Québec regions the following January.

Méthodes numériques (Numerical Methods)

LTEE conducted various projects during the year in pursuit of its mission to develop and demonstrate new electrochemical processes and electrotechnologies. Mention might be made first of the construction of a specially designed coil for heating the metal rolls used by the pulp and paper industry for drying and calendering paper. Specialists have also developed an industrial prototype of a compact, inexpensive high-power-density resistance and demonstrated the technological feasibility of an infrared-radiation furnace for drying flat, thick, heat-sensitive materials; they also determined the design criteria for this furnace. Another furnace combining infrared radiation and convection has been purchased as an addition to LTEE's facilities.

An exploratory study of the latest chemical electrosynthesis technologies was also performed during the year and several industrial plasma projects were pursued or completed. These include the commissioning of a 1-MW mobile unit for demonstrating plasma technologies and transferring them to industry.

MAGNETIC INDUCTION FOR HEATING CALENDERS

LTEE's induction heating laboratory continued its work on the heating of metal rolls used by the pulp and paper industry for drying and calendering paper. The objective is to be able to control the power applied across the rolls in order to obtain a better temperature profile. Induction heating is especially appropriate for this application and furthermore permits a high power density. The required local power control is achieved by juxtaposing a series of induction coils on the roll to create a number of heat sources. Each coil can be set and controlled individually and heats an area from 5 cm to 10 cm wide.



The coils developed by the LTEE research team are designed to function close to a surface at temperatures of up to 300°C. Their unit power is 4 kW over a width of 10 cm or 10 kW over 5 cm. A prototype comprising six 10-kW electrical sources operating in a frequency range of 10 kHz to 20 kHz was also developed. Related work is underway at other research centres, including Consolidated-Bathurst Inc., where 4-kW coils will be tested for hot calendering, and the Pulp and Paper Research Institute of Canada, where a coil and the 10-kW source will be used for impulse-drying tests.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

TECHNOLOGICAL FEASIBILITY AND DESIGN PARAMETERS FOR AN INFRARED FURNACE

A study was undertaken for Armstrong World Industries Canada to explore the possibility of electrifying the process used to dry acoustic panels at the company's Gatineau plant. The objective was to double the production rate through increased energy efficiency, while at the same time maintaining the high quality of the product. The new furnace also had to fit into the space taken up by a dismantled dryer. In-plant tests were carried out using a pilot furnace and a technique combining intermittent infrared and hot-air convection. This technique, which was developed at the LTEE laboratories, ensures rapid drying of thick, heat-sensitive materials.

The test results demonstrate that this technology can meet the given objectives and overcome production constraints. A set of design parameters has been established for its application to a new dryer. These include drying time, number of stages, and power distribution during the various phases of drying.

According to these parameters, the dryer will be 108 m long and have eight decks. The total capacity of the infrared sources will be 9700 kW; additional capacity of 1000 kW will permit better control over the temperature of the hot air recovered from the infrared sections and will help to start up the furnace after prolonged shutdown. The new dryer will be more economical and will occupy half the space of a standard convection furnace. It will have an energy efficiency of 65% to 70%.

The development of induction coils used by the paper industry for hot calendering was undertaken jointly by LTEE, Consolidated-Bathurst and the Université du Québec à Trois-Rivières.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

STUDIES CONDUCTED FOR INDUSTRY

Many laboratory and in-plant studies were conducted in 1988 for Hydro-Québec's administrative regions and for the *Groupe Marchés québécois* (Québec Markets). Some of the objectives were to evaluate the performance and parameters of certain industrial processes; to demonstrate the feasibility of various electrotechnologies; to define the design parameters for an electrical installation; and to assess the performance of new facilities.

Major in-plant activities included measurement of dye-water consumption for Satexil with a view to possibly installing an industrial heat pump; evaluation of a multiple-effect milk evaporator for Lactantia Ltd. to compare it with a new mechanical vapor recompression unit, which will be assessed in 1989; study of the performance of a dual-energy system for bread-baking at *La Boulangerie Doyon*; evaluation of the energy performance of mechanical extractors, infrared radiation preheaters, steam preheaters and gas drying stenters used by Consoltex in its fabric-finishing process; and, lastly, a study of American Air Filter's fibreglass manufacturing process with a view to conversion from gas fusion to electricity.

Many laboratory studies were also conducted to assess the technological feasibility of a wide range of concepts: microwave decontamination for laundries (*La Buanderie centrale de Montréal*); infrared sintering of alumina (*Aluchem*); radio frequency or infrared drying and dehydroxylation of lime (Timminco Metals); perlite expansion by conduction or infrared (Armstrong World Industries Canada); cocoa bean micronization by infrared radiation (Comet Confectionery); infrared predrying of fabrics (Geo. Sheard Fabrics Canada) and carpets (Peeters Carpets); infrared drying of silty marl (*Melri*);

infrared polymerization of resin in the fabrication of mica plates (Acim Industries); use of roller conveyors for infrared drying (Pyradia); and infrared radiation as a means of increasing the water extraction capacity of calcopyrite (Opemisca Mines).

Électrotechnologies industrielles
(Industrial Electrotechnologies)

PROTOTYPE HIGH-POWER-DENSITY RESISTANCE

A new type of high-power-density electric resistance element has been developed at the LTEE laboratories. Compared to the open-coil or sheathed tubular elements in common use, it offers a substantial reduction in the volume of industrial air heating systems. The main contributing factor is the use of the concept of porous materials, which has resulted in an increase in the surface available for heat exchange and in the intensity of heat transfer. The new element permits a power density of 12 MW/m³, which is 10 to 50 times that of existing technologies.

Another advantage is the cost of the new element, which is estimated at \$7 to \$12/kW, far lower than the \$38 to \$113/kW selling price of its conventional counterparts. Such an outstanding saving

is due to the use of readily available, relatively inexpensive materials. The heating element, for instance, consists of perforated stainless steel plates simply slotted together and assembled to form a block of electric resistances.

The latest prototype designed and tested uses one phase of a 216-kW three-phase (delta) assembly. Its 72 kW of power at 587 V enables it to raise the temperature of the ambient air from 31°C to 560°C with a pressure loss of 4.6 cm of water at 2.54 m/s, yet the element measures no more than 32 cm x 13 cm x 14 cm.

The new concept lends itself to a full range of applications, and not only at high temperatures. When more standard temperatures of hot air are required, for example, the power density can be increased.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

CHEMICAL ELECTROSYNTHESIS

In 1988, John E. Colman & Associates conducted an exploratory study of the new chemical electrosynthesis techniques that have emerged from research laboratories in order to identify those that offer the best market potential.

Several of these technologies are of great interest to industry, especially to manufacturers of ethylene glycol and terephthalic acid used for making synthetic fibres and biodegradable plastics, and to producers of ozone used as a substitute for chlorates for bleaching wood pulp. Discussions are now underway with various industrial partners with a view to establishing development programs for marketing these technologies. The electrosynthesis of ethylene glycol alone represents a potential of 125 MW.

A first multi-purpose pre-pilot test bench has gone into service. This facility, which consists of two electrochemical cells, will be used for feasibility studies of electrodialysis processes and other membrane-separation processes and, also, for various development projects in electrosynthesis.

Électrochimie (Electrochemistry)

MOBILE UNIT FOR PLASMA DEMONSTRATION

The 1-MW mobile unit to be used for demonstrating plasma technologies developed in Hydro-Québec's laboratories and transferring these technologies to industry has gone into service. It comprises three 15-m-long trailers. The control room and the rectifier are installed on the first. The second carries the cables and ducts for operating the plasma torches inside a plant up to 100 m from the place where the trailers are parked. The third transports the cooling units and the compressor. The torch power can be adjusted between 50 kW and 1 000 kW, and operation can be in transferred or nontransferred mode.

A 1-MW mobile unit is used to demonstrate plasma technologies and transfer them to industry. (Photo: Plasma Energy Corporation - United States)



Plasmas industriels (Industrial Plasmas)

INDUSTRIAL APPLICATIONS OF PLASMAS

The technology developed at the LTEE laboratories for recycling aluminum dross from smelting furnaces has been adopted by Alcan International at its 1-MW pilot plant in Jonquière. This transfer of a plasma-based technology, from LTEE to industry, has met with resounding success, and the many tests conducted in 1988 have further improved this process.

With respect to the application of plasma torches for opening tap holes in arc furnaces during operation, studies this year allowed the research team to define the parameters for plant tests to be performed early in 1989.

In addition, experience has shown the Plasmacan furnace to be highly suitable for processing ferroalloy fines. Low-power tests have been conducted for SKW Canada and others are underway for Elchem Metal Canada. Pilot tests are also planned in order to determine the economic feasibility of the process.

Plasmas industriels (Industrial Plasmas)

The LTEE laboratories have a new general-purpose conveyor furnace combining infrared radiation and convection to dry flat industrial products. The 128-kW infrared sources can heat surfaces of up to 1.27 m x 2.45 m, while the 60-kW air heater can generate temperatures of up to 175°C.

PLASMA PILOT PLANT

The LTEE 1-MW plasma pilot plant is now in operation. With a surface area of 250 m², the plant is equipped with a full system of process gas scrubbers as well as a data acquisition and processing unit. Several Plasmacan, crucible and rotating furnaces are available for testing in accordance with client specifications. A robot has been installed to allow plasma torches to be used for controlled surface treating and drilling.

Plasmas industriels (Industrial Plasmas)

COLLABORATION WITH UNIVERSITIES

LTEE personnel undertook a number of research projects in collaboration with Québec universities in 1988.

The Natural Science and Engineering Research Council (NSERC) approved our joint project with the *Centre de spécialisation des cultures abritées* at the Université Laval on the use of electrotechnologies for cultivation in greenhouses. Meanwhile, Hydro-Québec continued to perform technical coordination for

the agreement it signed with this centre regarding the use of electric lighting as a means of heating greenhouses.

Another new project was presented to the NSERC in collaboration with that university's *Groupe de recherche en sciences et technologie du lait*. It involves a pasteurization technique that consists in circulating milk in stainless-steel pipes heated by magnetic induction.

A contract was awarded to the Microbiology Department of the Université Laval for research on water heaters. LTEE installed a test bench at the university, and the Department began its microbiological studies. Hydro-Québec also commissioned McGill University's Metallurgy Department to conduct sintering tests on aluminum.

In joint projects initiated last year, the Université du Québec à Trois-Rivières worked on an induction coil with a special geometry for heating calenders used in the paper industry. In addition, a Hydro-Québec scholarship holder in a doctoral program at McGill University continued his work on the modeling of drying by various electrical technologies.

Électrotechnologies industrielles (Industrial Electrotechnologies)



One of the significant achievements of 1988 was the development of an automatic recording device for EHV transients, for which a manufacturing and marketing licence has been awarded. Other accomplishments include a data acquisition and control system for the cable-testing facility and the installation of a new measuring system for the test cells in the high-power laboratory.

The studies performed in 1988 covered dielectric stress distribution in power transformers, high-voltage fibre-optic control links, and the use of amorphous materials for water electrolysis. It should be pointed out that the materials characterization laboratory was reorganized during the year and equipped with several new instruments.

AUTOMATIC RECORDER FOR EHV TRANSIENTS

At the request of the *Direction Appareillage* (Apparatus), a team of high-voltage testing specialists designed and developed a broad-band 1-MHz digital recorder with a 10-bit resolution for measuring EHV transients in substations. Dedicated software is used to control the recording operation.

Signals from the high-voltage circuit are sent via a coupler installed on the bushing of a power transformer in the substation. The original design of this coupler, now patented, isolates the HV electric circuit from the measuring circuit in order to protect the recorder from variations in the reference ground potential. The control software triggers the recorder as soon as the pre-established magnitude or rate of rise is exceeded.



*Hydro-Québec
has developed
an automatic*



*digital recorder
for measuring
EHV transients
in substations.
Under a manu-
facturing and
marketing
licence granted
to ABB, this
system is now
manufactured
in Québec.*

A prototype of this recording device was put into service as part of a study of the magnitude and waveform of transients on Hydro-Québec's 735-kV transmission system. It recorded over 1000 transients, which were subsequently analysed in order to assess their influence on the internal insulation of power transformers. The results of this analysis provided a basis for drafting a new technical specification for future purchases of EHV power transformers.

Under a manufacturing and marketing licence granted to ASEA Brown Boveri, the research prototype is now being produced in Québec.

Mesure et Informatique

(Measurements and Data Processing)

Commercialisation (Marketing)

DATA ACQUISITION AND CONTROL SYSTEM FOR THE CABLE-TESTING FACILITY

Evaluation of the suitability of underwater cables for the Grondines-Lotbinière river crossing called for the development of a data acquisition and control system. The task was assigned to a research team, which responded with a PC 386 computer based on XENIX system software and connected to a multimeter and a multiplexer via a parallel link. The multiplexer has 76 analog inputs for thermocouples and 16 relay outputs. The system will eventually comprise three computers (one for each cable), which will be linked to the local ETHERNET network.

Meanwhile, an entire software package has been developed for the tests to be performed at the new testing facility. In view of the wide variety of tests expected, the research team has designed a dedicated language with an interpreter.

This will allow the parameters – acquisition and storage rate, global variables, etc. – to be defined together with the digital outputs (main contactor, current increase or decrease), alarms (minimum or maximum temperature, minimum or maximum current), and controls (for a given current source: minimum and maximum current, time delay from minimum to maximum). In addition, test engineers have access to keywords for planning their test programs. Software has also been developed for remotely consulting data on tests underway, consulting stored data, and plotting or tabulating results.

The tests on 25-kV and 315-kV cable models provided an opportunity to develop algorithms for constant-current control and temperature-dependent control (temperature cycling, reference temperature, limit of temperature variation between conductor and sheath). They also allowed engineers to validate the acquisition and control system from the hardware and software points of view. These tests were performed between October and December 1988, mobilizing resources in both the high-voltage and the high-power laboratories. Other tests are scheduled in March and May 1989, and the installation should be completed within the three months that follow.

Mesure et Informatique

(Measurements and Data Processing)

NEW MEASURING SYSTEM FOR THE HIGH-POWER LABORATORY

A project to replace the measuring equipment in the test cells at the high-power laboratory is now underway as a result of the successful development of a number of prototypes in 1988.

For example, a new type of controller has been designed for data acquisition. It offers a direct con-

nection between a data acquisition system and the random-access memory of a SUN workstation, at a transfer rate of up to 1 MHz. This new interface has not required any changes to the existing acquisition units. Its primary purpose will be to interconnect the Preston acquisition units in the new power system study and simulation centre.

Other developments include the fibre-optic link needed for the data transmission hardware and a communications interface for remote connection of the display terminal to the other components of the processing unit. The use of optical fibres will solve the interference problems due to noise generated by the high-power laboratory's test facilities. It also provides a means of linking a display terminal to a remote file server: in fact, tests have proven the reliability of this unit with SUN3 and SUN4 file servers for distances of over 400 m, without loss of accuracy.

These acquisition and communication interfaces meet a number of Hydro-Québec's needs. Furthermore, both are innovative products with a promising market potential.

The general design of the measuring units is now finished and development work has begun on the prototypes, which should be completed in 1989.

Lastly, a high-speed display algorithm has been developed for reproducing multipoint signals on the screen without any loss in precision. The algorithm has already been incorporated into several signal processing programs, including those employed by the study and simulation centre at IREQ and by the *Service Essais et Expertises techniques* (Testing and Technical Appraisals).

Mesure et Informatique

(Measurements and Data Processing)

SAFETY OF THE INTERNAL INSULATION OF POWER TRANSFORMERS

Utilities in North and South America are seriously concerned about the reliability of large EHV power transformers, which play a strategic role in power system operation. This concern prompted a team of researchers at IREQ to study the safety margin of the internal insulation of such power transformers. The stress due to system-generated transients was measured and compared to that produced by impulses applied during acceptance tests.

The voltage distribution was measured on the windings of typical transformers used on Hydro-Québec's power system. Disc-to-disc and disc-to-ground voltages were calculated for typical transient voltages measured in the field and during standard BIL and switching impulse tests. The comparison revealed the need for a higher switching-impulse withstand voltage level on the Hydro-Québec system, and the *Direction Planification du Réseau* (Power System Planning) has already taken steps to implement this modification.

Mesure et Informatique

(Measurements and Data Processing)

AMORPHOUS MATERIALS FOR WATER ELECTROLYSIS

A study has been conducted on the behavior of ribbon-like amorphous alloys during the electrolysis of water to produce hydrogen. The solutions used to test these alloys were strongly alkaline (30% wt KOH) and the temperature was raised to 70°C.

At high current densities, the alloys do not fulfil the standard requirements for industrial use and need to be activated chemically or electrochemically in order to improve their performance. Amorphous materials are generally characterized by a marked deactivation and a reduction of their physical integrity during the evolution of hydrogen, especially if one of the alloy components shows a strong affinity with hydrogen.

The current focus of these studies is the use of materials with a large specific surface area.

Chimie des matériaux (Materials Chemistry)

MATERIALS CHARACTERIZATION LABORATORY

The materials characterization laboratory was the scene of major modifications in 1988. First, it doubled in size and, second, the instruments were grouped according to function. Five categories were established: electron microscopy and image analysis; chemical composition analysis; study of electric, magnetic and thermal properties of materials; structural analysis by X-ray diffraction; and, lastly, surface preparation and analysis.

The laboratory also purchased new equipment. This includes a 300-kV Hitachi transmission electron microscope for forming magnified images of the atomic structure of materials, a Perkin-Elmer ultra-high-vacuum system for the preparation of coatings and production of thin films; an extra-high-sensitivity magnetometer; and a cryogenic system for studying the electric and magnetic properties of superconductors.

Technologie des matériaux (Materials Technology)

TESTING OF OPTICAL FIBRES

A study on high-voltage optical fibres for use as data transmission links on control circuits was completed for the Canadian Electrical Association in 1988.

To protect the transmission of data between the high-voltage test point and ground from the effects of electromagnetic interference, the communication medium must offer a high insulation level and be designed for long-term operation under the stresses imposed by high voltages. Optical fibres have intrinsic qualities that make them the ideal medium for such situations and they are therefore finding wider and wider use. However, the conventional methods for testing high-voltage fibre-optic (HVFO) links are not suitable for studying the aging process of the various materials, plastics in particular, employed in this type of product.

The aims of this research project were to identify commercial systems using optical fibres and to develop comparative test methods for evaluating the electrical performance of the HVFO links used in different assemblies.

Three categories of systems that use HVFO links were identified. Different types of test were then developed to assess the merits of each system. The test methods selected were the short-sample aging test, a thermoelectrical cycling test, a compatibility test and the International Electrotechnical Commission's salt-fog endurance test.

Électronique (Electronics)

Two new telerobotics projects got underway this year. The aim of the first is to design, develop and test a prototype remote manipulator arm for maintenance tasks on the overhead distribution system. The second project involves the development of telerobotics software; an agreement has been signed to this effect. Negotiations have begun with battery and thin-film manufacturers to study the possibility of setting up a pilot plant for the production of ACEP polymer-electrolyte batteries and to assess the market potential of room-temperature ACEP batteries.

Hydro-Québec and a German firm will soon begin studying the technical feasibility of a project to produce hydrogen in Québec and subsequently ship it to Europe. In another area, that of expert systems, a task force was created at Hydro-Québec to launch and develop a family of expert systems and promote the use and marketing of this form of artificial intelligence. In addition, work was pursued on the implementation of software as part of a pilot project to automate a distribution control centre. Other activities in 1988 included digital mapping and a supervisory-control system for dual-energy heating.

The Canadian Electrical Association gave a consortium formed by Hydro-Québec and CAE Electronics a mandate to design, develop and test, on the Hydro-Québec system, a prototype tele-robot for overhead distribution system maintenance.

TELEROBOTICS-RELATED ACTIVITIES

The past year was particularly rewarding for the robotics team in that it saw the launching of two major projects.

First, the Canadian Electrical Association gave a consortium comprising Hydro-Québec and CAE Electronics the mandate to design, develop and test a prototype tele-robot for overhead distribution system maintenance. International Submarine Engineering, the University of British Columbia and McGill University will work as sub-contractors for CAE Electronics,



while Hydro-Québec will work mainly with companies and laboratories located in Québec. The project consists in fitting a truck with a partly automatic, remote-controlled manipulator arm for carrying out certain live-line tasks on the overhead distribution system. The main advantage of this technology is that it will allow Hydro-Québec to assure customer service continuity during maintenance interventions, while respecting personnel safety requirements.

The second project is the development of software for telerobotics. An agreement to this effect has been signed between Hydro-Québec, the Computer Research Institute of Montreal and McGill University.

Meanwhile, the robotics laboratory was engaged in a wide range of activities: testing of a force wrist for dynamic control of the robots; production of vision algorithms for tie-wire characterization and insulator positioning, and development of an expert system for handling errors; development of a tool for cutting tie-wires; continuation of a feasibility study on the robotiza-

tion of an underground distribution system (jointly with the *Direction Distribution* (Distribution); and, lastly, in collaboration with Bell Canada and the *Association québécoise de la fibrose kystique*, the development of a prototype percussion instrument for cystic fibrosis patients.

Électronique (Electronics)

Projets de développement (Development Projects)

ACEP PILOT PLANT

Efforts to market the ACEP polymer-electrolyte battery gave rise to many activities in 1988. For example, studies are now underway to prepare for demonstration of the ACEP technology. Their aim, principally, is to evaluate the technical and economic aspects of the pilot facilities needed to produce a small ACEP battery for ambient-temperature applications.

In addition, intense negotiations have been conducted with a leading battery manufacturer and an internationally renowned polymer-film manufacturer with a view to creating a consortium for industrial-scale production and exploring the market for ACEP products. If these prospective partners confirm their interest in the technology developed by Hydro-Québec and its market potential, letters of intent should be signed in 1989.

Projets de développement (Development Projects)

INTERCONTINENTAL HYDROGEN TRANSPORTATION PROJECT

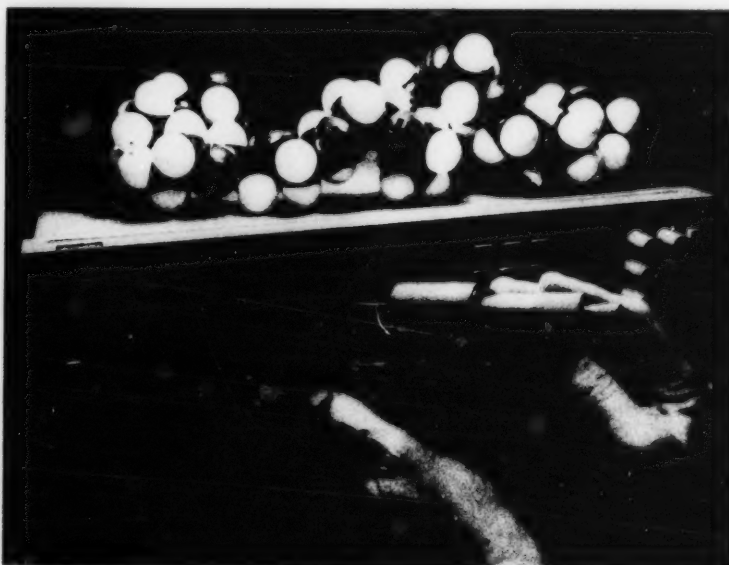
Under an agreement to be signed with the European group Ludwig-Bölkow-Stiftung (LBS), Hydro-Québec will take part in a feasibility study of the intercontinental transportation of energy in the form of electrolytic hydrogen. This agreement follows months of negotiations between the Québec government and the Commission of the European Communities.

The objective of the feasibility study is to identify the technical and economic parameters of a demonstration project involving the construction of a large (100-MW) electrolysis plant in Sept-Îles, Québec. Under the agreement between Hydro-Québec and LBS, the partners will jointly establish a project management group to define work assignments, award contracts, manage funds, etc.

The estimated cost of the two-year study is \$4 million, to be shared equally by Québec and LBS.

Projets de développement (Development Projects)

Studies are being performed to evaluate the technical and economic aspects of the pilot facilities needed to produce ACEP batteries for ambient-temperature applications. Negotiations leading to the creation of an international consortium for industrial demonstration purposes are also underway.



TASK FORCE ON EXPERT SYSTEMS

Research on artificial intelligence has produced computerized tools, known as expert systems, which are designed to assist decision-makers by providing them with the required knowledge base in specific domains.

Hydro-Québec is very aware of the importance of such tools and has begun to develop expert systems at every operating level: generation, transmission, distribution and utilization. In 1988, it decided to create a task force to initiate and develop expert systems in these four areas of activity, to monitor their implementation at Hydro-Québec and to orient the related marketing activities.

Six projects were approved in 1988:

- **ENERGEX**, an expert system preprototype for facilitating use of the ENERGIE III model;
- **EXSEMBLE**, an expert system prototype for the preparation of substation layouts, which will be applied first to design a type II 120-25 kV substation;
- **GESTAL**, an expert system for alarm management in regional operating and control centres;

- **SAGE**, an expert system prototype for management of energy exchanges between neighboring systems;
- **TRANSEPT**, an expert system prototype for transmission system design;
- **SUBAREX**, an expert system preprototype for dam surveillance.

Projets de développement (Development Projects)

AUTOMATION OF THE ST-LAURENT DISTRIBUTION CONTROL CENTRE

Three computer programs covering anomalies, hold-offs, and medium-voltage customers have been implemented at St-Laurent distribution control centre as part of an automation pilot project. In addition, finishing touches were put to a newly developed system for processing failure-related telephone calls (START) and a system for simulating the execution of a switching scheme. Automation-related purchases so far include 27 microcomputers, a server and system restoration equipment.

Digitization of 237 lines in the eastern sector of Montreal has been completed and the results are now in the hands of the St-Laurent Region draftsmen for validation purposes. A total of 23 demonstrations for Hydro-Québec employees and representatives of various outside firms were presented in 1988. In addition, the *Direction Distribution* (Distribution) invited the group to present a paper on its computer programs at a colloquium held in November.

Projets de développement (Development Projects)

COMPUTER-ASSISTED MAPPING

A successful pilot experiment undertaken in the framework of an agreement between Hydro-Québec and Bell Canada provided the opportunity to demonstrate the feasibility of transferring cartographic data between these companies' computer systems. A study was also conducted to assess the merits of joint surveying and to examine strategies for obtaining the required cartography.

Projets de développement (Development Projects)

REMOTE CONTROL FOR DUAL-ENERGY SYSTEMS

A project was initiated in November 1988 to install 300 remote-control units for dual-energy systems used to heat institutions, commercial buildings and industries in six regions of Québec.

With these remote-control units, Hydro-Québec will be able to transfer the customer's energy source directly from its system control centre in Montreal via a microwave link. At peak periods, transfer from electricity to natural gas, for example, will contribute to more efficient load management on the Hydro-Québec power system.

The project provides an opportunity to assess the possibility of optimizing the product for marketing purposes.

Projets de développement (Development Projects)

A study was conducted of a 21-kWh installation with a view to developing a battery for powering electric vehicles. Activities related to the Varennes tokamak are now under the management of the Canadian Centre for Magnetic Fusion (CCMF). The tokamak was dismantled last fall, after more than a year of operation, so that the internal coils and structures could be installed in 1989.

With regard to superconductivity, an industrial consortium has been set up to develop the technologies for manufacturing prototype superconductors and a study was performed of potential applications of superconducting materials in the electric utility industry.

Hydro-Québec carried out a design study this year for a 21-kWh battery installation in order to develop an ACEP battery adapted to electric-traction vehicles.

BATTERIES FOR ELECTRIC TRACTION

A significant milestone in the long-term research into batteries for powering electric vehicles was reached this year in the form of a design study for a 21-kWh battery installation. The study was based both on the characteristics and performances of laboratory cells and on the results of economic and technological feasibility studies. The findings confirm that polymer-electrolyte lithium batteries can meet the power and energy density, cyclability and cost criteria established by the US Department of Energy for an urban delivery van;



accordingly, Energy, Mines and Resources Canada awarded a contract to adapt this study to a Canadian context. Research on the technical aspects is focused on optimizing the cycling performances and understanding the aging phenomena.

Chimie des matériaux (Materials Chemistry)

INITIAL ACTIVITIES AT THE CCMF

The Canadian Centre for Magnetic Fusion (CCMF) gradually took over activities related to the Varennes tokamak during the year. Created at the end of 1987, the CCMF is an independent organization funded mainly by Hydro-Québec, Atomic Energy of Canada Limited and the *Institut national de la recherche scientifique*.

The Centre was originally mandated to operate the tokamak within the framework of Canada's National Fusion Program but its mission has expanded slightly in an international direction. In fact, Canada is now preparing to contribute to the ITER project launched by Europe, the United States, Japan and the USSR for the development of a large fusion reactor. Steps already taken in this new context include the recent signing of a memorandum of agreement by Canada and Europe.

The past 12 months produced many rewarding scientific results and technological achievements. While theoretical studies maintained a steady pace, the major emphasis was on obtaining experimental results before the refit program, which involves partial disassembly of the tokamak to install the internal coils.

In addition to its contributions in the form of program funding and an experienced research team, Hydro-Québec makes premises available to the CCMF and provides administrative support services such as accounting and procurement.

Fusion (Fusion)

TOKAMAK OPERATION

The TAI team assigned to the CCMF took an active part in the optimization of tokamak discharges in order to obtain reproducible plasmas for detailed study of the parameters. A maximum plasma current of 293 kA was reached and reproducible impulses very close to that limit were attained. No major obstacle was encountered in achieving such performances, which testifies to the excellent magnetic geometry of the device. Further evidence of this characteristic was provided by the observation of highly energetic electrons undergoing several million revolutions in the toroidal core. Successful production of the first multiple-pulse plasmas in 1988 confirmed the feasibility of using the planned high-duty-factor approach in the next stage of experiments.

Work on assembling the internal coils and structures in the electromechanical workshop of TAI's own technical services continued throughout 1988. At year-end, the tokamak operation was halted to allow dismantling of the diagnostic

systems and subsequent installation of these internal coils. Operation is scheduled to resume in fall 1989.

Fusion (Fusion)

HIGH-FREQUENCY AUXILIARY SYSTEM

The Hydro-Québec team contributed to the design of a 1-MW high-frequency auxiliary system for the Varennes tokamak. This system will serve to sustain a plasma current on the order of 200 kA and thereby help to increase the current-pulse duration from 1 s to 30 s. Various theoretical studies are now underway to shed light on the current-drive and plasma-heating phenomena that the auxiliary system will generate. The team also undertook a study of the characteristics of the complex apparatus and subsystems needed to implement this auxiliary system.

Fusion (Fusion)

LASER DIAGNOSTICS

The TAI team assigned to the CCMF installed the first optical diagnostic – the submillimetric interferometer – on the tokamak during the first six months of 1988. This experimental device, which comprises an infrared laser designed to measure the electron concentration on six different transversal chords, was built at IREQ. The signals are deconvoluted to reproduce the radial profile of the electron density throughout the duration of the plasma pulse.

The latter half of the year saw the installation of a second diagnostic, the coherent-diffusion CO₂ laser, used for measuring the characteristics of electron density fluctuations.

Lastly, the Thomson diffusion diagnostic was assembled and installed. A powerful neodymium laser source illuminates the plasma, while an ultrasensitive spectrometer analyses the light diffused by the electrons in order to determine the temperature by means of the Doppler effect. After a long period of calibration and adjustments to reduce stray light, the diagnostic is now in continuous operation, allowing the temperature at the centre of the plasma to be determined every 20 ms.

Fusion (Fusion)

X-RAY DIAGNOSTICS

The imaging system used to record soft X rays emitted by the plasma now comprises five sets of 16 detectors. It provides two-dimensional tomographic reconstructions of the X-ray emission which, among other things, allow highly original studies of fluid instabilities at the centre of the plasma.

The four arms of the multi-channel spectrometer for measuring soft X rays were gradually installed over the year. This instrument will be used for simultaneously determining the electron temperature

and the level of impurities in the plasma at four different positions, from the spectra of the X rays emitted.

TAI personnel's work on these two systems represents a significant contribution to CCMF activities in 1988.

Fusion (Fusion)

THEORETICAL AND INTERPRETATION WORK

The theoretical research activities of the TAI team assigned to the CCMF focused on three aspects in 1988: heating and current drive at the lower hybrid frequency; MHD equilibrium and stability during forced current rampdown; and simulation of the edge plasma and the diverter. The team also simulated tokamak operation using radio-frequency current drive and estimated future power requirements. Forced current rampdown without instability seems possible, suggesting that the device will be easy to operate at a high repetition rate.

Fusion (Fusion)

SUPERCONDUCTIVITY

A consortium comprising Hydro-Québec, Atomic Energy of Canada Limited and Canada Wire and Cable Limited has been created to study superconductivity. The consortium will receive funding under the National Research Council Canada's Industrial Research Assistance Program.

Two recent breakthroughs have widened the scope of possible applications for superconductivity.

The first is the discovery in 1987 of high-critical-temperature superconducting materials that can operate at the temperature of liquid nitrogen (-196°C). The second is the development of low-loss AC wires based on traditional superconducting materials that operate at the temperature of liquid helium (-269°C).

The results of a study sponsored by the Canadian Electrical Association show that superconductivity has particularly interesting potential in the area of electrotechnology.

For example, in power generation, if the field windings of a generator could be replaced by superconducting coils, losses now in the vicinity of 3% could be halved. Other advantages at the generation level include more compact equipment, higher specific power ratings and lower synchronous impedances with beneficial effects on power system stability.

As far as power transmission is concerned, superconducting cables could prove very useful in situations where overhead installations are impossible or undesirable, as in urban areas, for instance, where right-of-way is limited.

Two superconductivity applications have already been identified as offering potential for energy storage: daily load leveling and power system stabilization.

Lastly, with respect to the use of electricity, the focus is on large electric motors, whose losses are estimated to account for as much as 1% of Hydro-Québec's total production. Energy efficiency would be greatly enhanced if superconducting windings were used in such motors.

Technologie des matériaux (Materials Technology)

A new cable-testing facility specially designed for high-voltage underground cables is under construction as part of the project involving the Grondines-Lotbinière under-river crossing.

In addition, the new power system study and simulation centre is nearing completion. Offering twice the capacity of the existing facility, the new centre will allow permanent representation of the Hydro-Québec power system as well as simultaneous studies of its dynamic performance.

The LTEE laboratories, meanwhile, have been equipped with several new facilities: a general-purpose continuous furnace combining infrared radiation and convection; a second continuous furnace specially designed for heating aggregate and mineral ore; a high-temperature furnace; and a magnetic-conduction heater for tanks. The heat-pump test bench has been transferred from IREQ to the LTEE site.

Lastly, a new fire protection system was installed in the high-voltage laboratory during the year.

NEW POWER SYSTEM STUDY AND SIMULATION CENTRE

Anxious to be able to meet future needs, Hydro-Québec began work on the construction of a \$10-million power system study and simulation centre in Varennes which will double the capacity of the existing centre. The new facility will allow simultaneous studies on the dynamic performance of the power system, such as operation optimization studies, power system planning studies for the revision of the utility's transmission system design criteria, and integration and commissioning studies for interconnections and compensation equipment.

Construction of the 2142-m² building began in August and should be completed in January 1989. The sustained effort of the prime contractor, the *Vice-présidence Équipement de transport* (Transmission Facilities), ensured that the work remained on schedule.

As far as the equipment for the new centre is concerned, multi-terminal HVDC control systems have already been purchased, while a data acquisition and processing system has been designed and tested. Production is underway on other components required for line modeling, such as filters, transformers, surge arresters and valves.

The commissioning date is set for December 1989.

Études de réseaux (Power System Studies)

UNDERGROUND-CABLE TEST FACILITY

A new facility for testing high-voltage underground cables is under construction at IREQ. This facility, which is part of the project involving a cable crossing under the St. Lawrence River between Grondines and Lotbinière, will play a strategic role in Hydro-Québec's future activities, since underground cables represent a new technological springboard. The facility is scheduled to go into service in August 1989. Construction is under the direction of the *Vice-présidence Équipements de production et Édifices* (Generating Plant and Buildings).

The purpose of the testing and demonstration program is essentially to check all components of the ± 450 -kV DC under-river link and evaluate their long-term performance under conditions that simulate actual operating conditions. The same facility will also be used to study AC cables up to 735 kV.

With a total surface area of about 20 000 m², the test facility will comprise the following equipment: an alternating-current source (1.2 MV), a direct-voltage source (1.2 MV, 50 mA), an impulse generator (3.6 MV, 360 kJ) and three alternating-current sources (4000 A). A 25-kV/600-V, 5-MVA supply substation will be built to house this equipment, while the measurement and data acquisition system will be installed in a new 160-m² control building. When completed, the new test facility will be able to accommodate three cable loops approximately 125 m in length, together with their bushings and related hardware.

Laboratoire Haute tension (High-Voltage Laboratory)

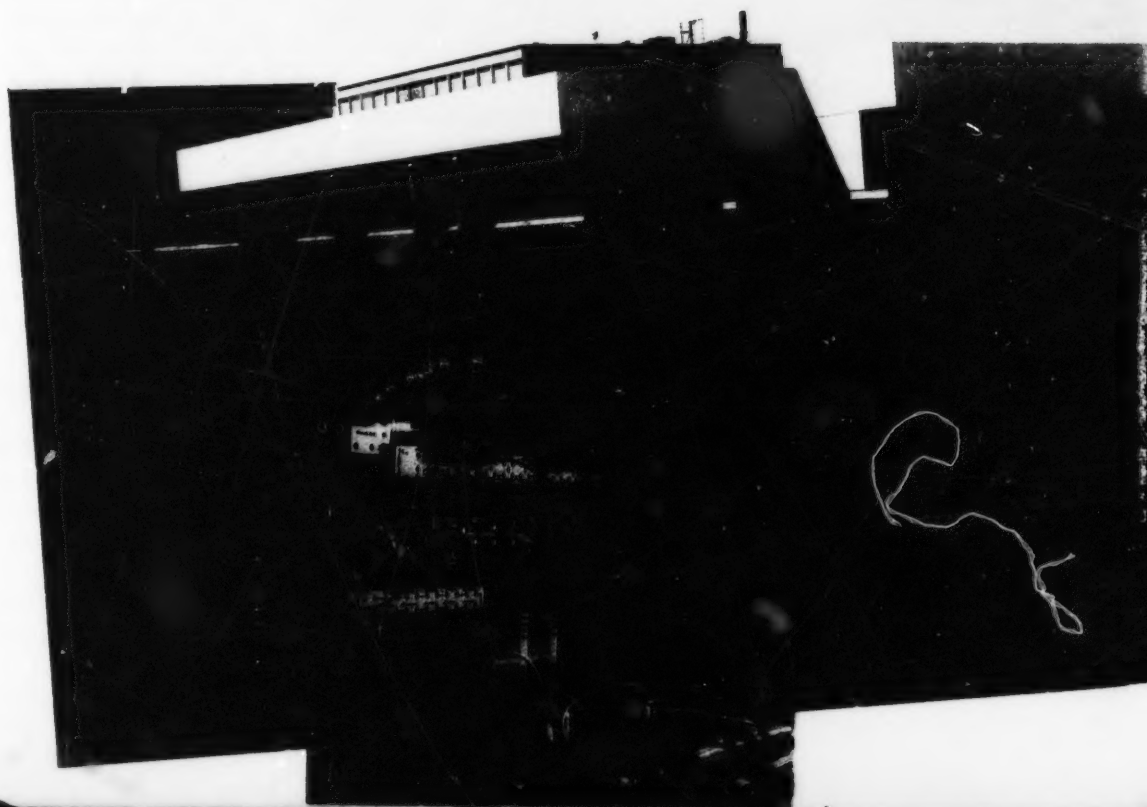
ADDITIONAL FACILITIES FOR LTEE

Electrotechnology-related activities at LTEE in 1988 burgeoned as new equipment was installed.

The first acquisition was a general-purpose continuous furnace combining infrared radiation and convection heating. It will be used to demonstrate its drying capability for flat industrial products. The conveyor is 1.27 m wide and has a reversible variable-speed (up to 0.5 m/s) motor. The 128-kW infrared heating modules along both sides of the conveyor can heat surfaces of up to 1.27 m x 2.45 m, while the 60-kW air heater can generate temperatures of up to 175°C.

The new power system study and simulation centre will double the capacity of the existing centre and allow simultaneous studies on system behavior. Commissioning is scheduled for late 1989.

Tests are underway at the manufacturer's plant on another continuous furnace, specially designed for heating aggregate and mineral ore. Infrared radiation and resistance heating are used in this case. The furnace has two levels, allowing materials to be passed several times. Each level is equipped with a conveyor, 0.6 m by 3 m, operating at speeds of up to 0.17 m/s. Scrapers installed along the conveyor draw the material onto fixed plates heated by electric resistances. Thus the material is turned



over continually and exposed to radiation by the infrared heating modules above. The total power of the infrared sources is 170 kW and of the heating of the conveyor itself, 90 kW. A 36-kW air heater permits temperatures of up to 200°C.

A new high-temperature furnace has also been added to the furnace room. Although originally designed to heat industrial products at temperatures reaching 1260°C, this versatile furnace lends itself to such different processes as the sintering of ceramic powders, dehydroxylation and decarbonization of lime, and regeneration of activated carbon.

The LTEE laboratories have a new dryer-conveyor for drying and heating aggregate and mineral ore.

behavior in various operating modes: heating, propane auxiliary, air conditioning, defrosting, etc.

Électrotechnologies industrielles (Industrial Electrotechnologies)

FIRE PROTECTION SYSTEM

The risk of fire is relatively high at laboratories such as Hydro-Québec's, which uses a great deal of equipment that may contain large quantities of oil. Accordingly, a new fire protection system was installed this year. It comprises:

- an oil-recovery tank
- a pumping station with a capacity of close to 7000 L/min
- four remote-controlled foam guns in the main hall
- a foam sprinkler system in the laboratory annex
- a sprinkler system in the offices.

In addition, oil-retaining walls have been installed around large-oil-volume equipment in order to contain any spillage.

These facilities will enable the members of the laboratory's fire protection team to act rapidly and efficiently in the event of an incident and to limit any damage.

Laboratoire Haute tension (High-Voltage Laboratory)



Meanwhile, a magnetic-induction heater for tanks, baths and similar containers went into service. This 12-kW unit offers a safe, energy-efficient way of heating all types of fluid or liquid – wax, acids, paint, chemicals, liquid foodstuffs, etc.

The heat-pump test bench formerly located at IREQ was installed at the LTEE laboratories. It had been intended for tests to assess the efficiency of heat pumps for home heating but it will now serve also for developing a heat-pump system with a non-electric (propane) auxiliary heat source. This combination could help reduce electricity consumption during winter peaks. The test bench will be used to determine the electrical and thermal performance characteristics of heat pumps and to simulate their

Several agreements were signed in 1988 for the marketing of products developed by Hydro-Québec. One involves the creation of Strateck Technologies International, which will market MECO (Mainframe External Control of Operations) software for the control of central computers. Another agreement was signed with ASEA Brown Boveri. This three-year, \$4-million contract concerns the testing of HV apparatus in Hydro-Québec's laboratories. Yet other agreements were signed with Ferranti-Packard and Tecrad for the construction of amorphous-core transformers and marketing of the micro-ohmmeter, respectively.

CREATION OF STRATECK TECHNOLOGIES INTERNATIONAL

Strateck Technologies International, a joint venture launched by TAI with its partners, the Hydro-Québec subsidiary Nouveler and the Montreal firm Roy, Bourassa et Associés, will soon start to market MECO, a software package developed by the utility's computer specialists.



MECO (Mainframe External Control of Operations) uses an IBM PC or PS2 computer to automate the control functions of an IBM or IBM-compatible central computer, thereby complementing the latter's control software. Its main functions include planning of operational activities; monitoring and analysis of requests from the central computer; remote control of central computers; and initiation of alarms to warn support and operations personnel of hardware or software problems.

Market studies confirmed the commercial potential of MECO. One asset is that it is designed for IBM and IBM-compatible central computers, which represent 60% to 70% of the market, or 7 000 to 10 000 installations throughout the world. Another is that it has an estimated two-year lead over competitive products. Hydro-Québec has been using this software since last February.

Commercialisation (Marketing)

A completely safe lightning arrester was developed in collaboration with Joslyn Canada.

MARKETING ALCID AND SICC SOFTWARE

The ALCID and SICC systems developed by the *Groupe Équipement* (Installations) will soon be available in the private sector as part of a technological transfer.

These microprocessor-based systems mark a great forward stride in station operation. ALCID is a system of automatic local controls and remote control based on distributed intelligence and is designed for substations, whereas SICC, which was developed in parallel, covers the same functions but for generating stations. The new systems will replace the relay technology currently used for this purpose,

each function calling for a separate set of relays. ALCID and SICC offer a means of incorporating all the standard functions, and many new ones, into a single system as needs appear. The software approach thus represents great space savings and reduced investment in equipment.

The market potential of ALCID and SICC was apparent from the outset, and, now that the development work is finished, this technology may be transferred to a private company in exchange for an interest in its capital stock.

Commercialisation (Marketing)

MARKETING LICENCE FOR FERRANTI-PACKARD

Hydro-Québec has granted Ferranti-Packard a licence to manufacture and market a new type of transformer developed by a team of researchers in 1985. The distinguishing feature of this transformer is its amorphous-steel core, which reduces magnetic losses to a minimum.

Ferranti-Packard is currently working on industrial prototypes of the transformer and plans to begin mass production at its Trois-Rivières plant, which is already building some 20 000 conventional transformers a year.

The new transformer will be marketed in Canada, the United States and Mexico as well as in the United Kingdom, possibly by the British firm Northern Engineering Industries, Ferranti-Packard's parent company, which has expressed an interest in distributing this product.



The licence follows an agreement signed last November for the manufacture of conventional distribution transformers. Under that agreement, Ferranti-Packard will also undertake research and development for Hydro-Québec projects.

Commercialisation (Marketing)

MARKETING OF THE IREQ MICRO-OHMMETER

Hydro-Québec and Tecrad have signed a licensing agreement for marketing an instrument designed and developed at IREQ: the micro-ohmmeter. The Québec firm Tecrad was originally contracted in 1985 to manufacture prototypes. The first was designed for electrical resistances down to $0.01 \mu\Omega$ and was limited to a maximum value of $20 \mu\Omega$. Tecrad engineers have since added new scales so that the instrument can now measure electrical resistances up to 200 m.

The micro-ohmmeter was designed at the request of the *Service Appareillage* (Apparatus) in the Manicouagan Region and was first used in that region to detect faulty electrical connections on generators during maintenance work at Bersimis 1 generating station. It was also adopted for nondestructive tests related to the construction of the Varennes tokamak.

Prior to the invention of the micro-ohmmeter, quality control of the welding of joints on heavy-current conductors posed a serious problem because the measuring instruments were not sufficiently sensitive and proved cumbersome and difficult to carry from site to site. Yet measurement of the electrical resistance of welds, which is very low (a few micro-ohms), is an essential parameter for assessing the quality of welded joints. The micro-ohmmeter offers a solution to this problem in that it allows the electrical resistance to be measured to the nearest $0.01 \mu\Omega$. Furthermore, it is lightweight and easy to handle.

Tecrad is a high-technology firm with offices in Ontario, the United States, France and Japan. Its directors are confident that the new instrument will arouse interest and the order book is already long.

Commercialisation (Marketing)

AGREEMENT WITH ASEA BROWN BOVERI

Under an agreement signed at the end of 1988, the high-voltage laboratory will perform tests on HV apparatus for ASEA Brown Boveri (ABB) over a period of three years. The contract is worth approximately \$4 million.

The apparatus consists of AC power transformers rated 10 to 750 MVA, shunt reactors rated up to 135 Mvar, current transformers for power systems operated at up to 765 kV and converter transformers for DC systems operated at up to 600 kV. Apparatus with even higher ratings than ABB can build may also be tested.

Commercialisation (Marketing)

Laboratoire Haute tension (High-Voltage Laboratory)

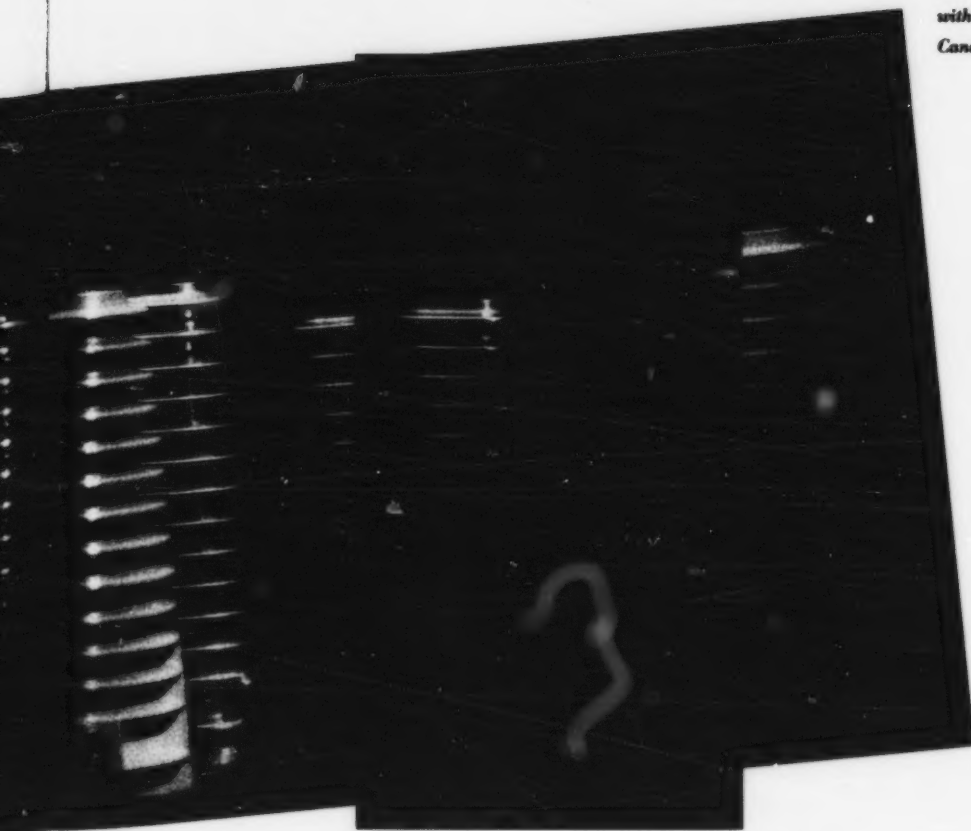


In 1988, TAI conducted a number of research, development and demonstration projects in collaboration with industrial partners. A list of the different corporations involved is presented below:

AAF-Canada
Acim Industries
Alcan International
Aluchem
Appareillage électrique (1987)
Armstrong World Industries Canada
ASEA Brown Boveri
Atlas Stainless Steels
Atomic Energy of Canada Limited
Bell Canada Entreprises
BELT - Bureau d'études
de lignes de transport
B.G. Checo International
Buanderie centrale de Montréal
Bushing Company (UK)
CAE Electronics
Canada Wire and Cable
Canadian General Electric Co.
Cegelec

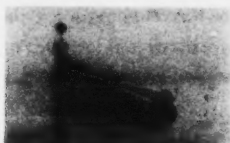
*A completely
safe lightning
arrester was
developed
in collaboration
with Joslyn
Canada.*

Comet Confectionery
Computer Research Institute
of Montreal
Consolidated-Bathurst
Consoltex
Contrôles PSC, Les
CRIM - Computer Research
Institute of Montreal
Cyme International
Elkem Metal Canada
Electrical Equipment Co. (USA)
Electrolyser
EPRI - Electric Power Research
Institute (USA)
Erco
Federal Pioneer
Ferranti-Packard
Georgia Power Co. (USA)
Geo. Sheard Fabrics Canada
G. & W. Electric Co. (USA)
IBM Canada
Innovation technologique INTEK
Joslyn Canada
Lactantia
Lyster Industries
Melri
Multi-Marques
Ohmweve Company (USA)
Opemisca Mines
PAPRICAN - Pulp and Paper
Research Institute of Canada
Peeters Carpets
Premiair Technology
Pyradia
Roy, Bourassa et Associés
Satexil
SKW Canada
Stoody Deloro Stellite
Strateck Technologies
International
T. Dan Bracken (USA)
Tecrad
Teshmont
Timminco Metals
Trench Electric
Unisys Canada
Vibro-Meter
Volta Énergie
Westinghouse Canada
Westinghouse Electric (USA)



During the year, Hydro-Québec, through its subsidiary Hydro-Québec International, continued to promote and market its expertise as an electrical utility on a world scale. Services are now being provided to various companies and government agencies in some 20 countries in Africa, Asia and Latin America.

AFRICA



ALGERIA

The feasibility study of a pumped-storage plant at Beni-Haroun, which was undertaken in association with Rousseau, Sauvé, Warren and Lalonde, Girouard, Letendre, was completed in 1988.

The project involved building a retaining structure in order to create a reservoir for the 795 million m³ of water to be used to supply the city of Constantine, to irrigate the highlands on the Saharan side of the region and to produce 400 MW of electricity at peak periods.

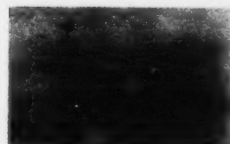


CAMEROON

The comprehensive training and technical assistance program begun several years ago with Cameroon's national electricity company, SONEL, is still underway. Some 15 Hydro-Québec specialists in various areas of the electrical utility industry are now working at SONEL under agreements to provide cooperation and institutional support.

The training program set up in 1985 for SONEL engineers, technicians and managers this year took the form of courses at Québec educational institutions and training sessions at Hydro-Québec.

Work was pursued on the development study for the Nachtigal project which involves the construction of a 260-MW generating station on the Sanaga River.



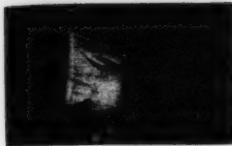
IVORY COAST

The Hydro-Québec specialist seconded to the Ivory Coast's Department of Industry in 1987 continued his work as technical advisor responsible for follow-up in the energy sector.



GUINEA

A second technical assistance agreement with SNE, Guinea's government-owned utility, was signed in 1986 and completed this year. The project was carried out by a team of 13 specialists in various fields, who are fully integrated into SNE's corporate structure. Other services have also been rendered pending renewal of the agreement.



MADAGASCAR

A planning study was undertaken to establish an initial minimum-cost expansion plan for the country's generating and transmission systems. This project entails rate studies as well as a comprehensive technical assistance and training program for the government-owned utility. The studies and training activities will be carried out in 1989, with the technical assistance continuing into 1990.

In addition, a study on reducing power distribution costs was performed in 1988. It recommended certain immediate improvements, as well as a pilot project using the effectively grounded system adapted to the local context.

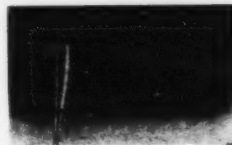


MALI

In 1988, HQI completed an engineering study of a 150-kV line running between Bamako and Ségou, four years after it began. This 230-km line will constitute one of the main arteries of Mali's electric grid and will supply a number of 15-kV and 30-kV medium-voltage networks.

In conjunction with this study, HQI prepared tender calls for the construction of the line and analysed the bids in readiness for the awarding of the contracts.

HQI formed a consortium with Tractebel and coordinated the activities leading to the implementation of the project. It will also supervise construction.



MOROCCO

A Hydro-Québec specialist in live-line work on EHV transmission lines carried out a survey of Morocco's needs in this area for the country's national electricity board.

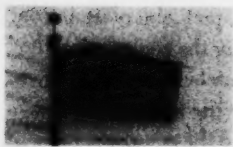
Meanwhile, preliminary studies got underway for the construction of a mini-hydroelectric generating station near the village of Zawyat-Ahançal and the construction of rural distribution lines in the Tafraoute and Tinerhir regions.



SENEGAL

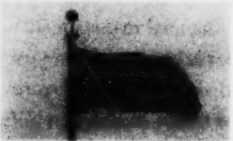
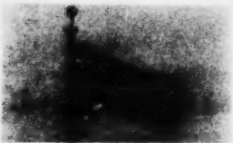
Three Hydro-Québec specialists are still acting as technical advisors on the operation of generating, transmission and distribution facilities and on financial management and customer accounting. They were seconded to Senegal's government-owned utility in 1987.

The training program for Senegalese personnel continued, both in Québec and Senegal, and work began on a feasibility study on the proposed national dispatching centre.



ZAIRE

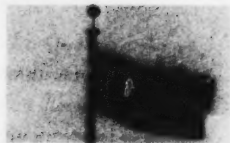
In addition to pursuing the studies initiated in 1983 on the stability of the N'Zilo dam, HQI launched a training program for engineers and technicians at the government-owned utility.



DEVELOPMENT OF THE SENEGAL RIVER

In 1988, progress was made on HQI's feasibility study of the transmission line to carry power from Manantali generating station to Senegal, Mali and Mauritania, the three member countries of the organization responsible for the development of the Senegal River. This study is being carried out in collaboration with *Tractebel* and *ÉDF International*.

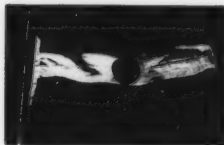
ASIA



BANGLADESH

A team of a dozen Hydro-Québec specialists completed the second phase in the development of a national system control centre for the Bangladesh Power Development Board (BPDB). During the first phase, initiated in 1984, 15 transmission substations and generating stations were connected to the control centre. Phase two brought this number to 40.

HQI carried out five separate studies of improvements to the operating and maintenance methods used in BPDB generating stations and transmission substations.



INDIA

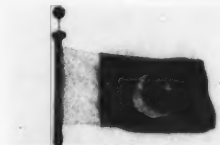
TAI's power system studies specialists continued to collaborate on a special research and development project approved by the Indian Planning Commission. The aim of this project is to build up national expertise in HVDC system design, installation and operation.

India intends to acquire this expertise by building an experimental HVDC link some 200 km long, to

be operated at 200 kV, 400 MW. HQI lent technical assistance to Bharat Heavy Electric, the firm responsible for this project, in a number of areas:

- It participated in developing the test program for the converter control systems and analysing the results. The tests were performed successfully at the Central Power Research Institute (CPRI) in Bangalore.
- It took part in the preparation of substation layouts, insulation coordination and site inspections during construction of the converter stations.
- It helped to design and determine the location of the ground electrodes and, also, of the lines linking these electrodes to the substation.
- It also helped to develop the design criteria and specifications for the telecommunications system linking the two converter stations.

The commissioning program will be completed in 1989.



PAKISTAN

In collaboration with Sogex, Hydro-Québec performed a feasibility study of a generating station comprising six bulb turbine-generator sets for a total of 120 MW. The station is to be built near the Taunsa dam on the Indus River.

Hydro-Québec also carried out studies of the hydraulic machines, estimated the costs and provided expertise in geotechnics and hydraulics.



PEOPLE'S REPUBLIC OF CHINA

Hydro-Québec continued to provide technical assistance to the various electrical research institutes in this country. Specialists visited China to give seminars, especially on power system management, while Chinese engineers came to Québec to participate in training sessions in areas related to Hydro-Québec activities.

The Three Gorges technical and economic feasibility study undertaken in 1985 was completed. A complementary study on the same part of the Yangtze River was initiated to explore aspects brought to light in the first investigation.

Lavalin, SNC, Acres Canada and B.C. Hydro International collaborated with HQI on a study of the following aspects of the project: sedimentation, environmental impact, relocation of the population, energy planning, construction scheduling and cost estimation.

The purpose of the Three Gorges Project, which involves the construction of a dam on the Yangtze River, is threefold: flood protection for local areas in the valley, improved navigation and the construction of a 13 000-MW power station.

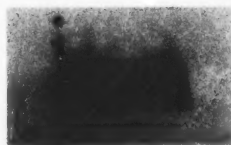
LATIN AMERICA



COLOMBIA

In cooperation with Sistecom in Bogotá, HQI has carried out various studies aimed mainly at reducing electric losses on the distribution network in the city of Cali. This work entailed not only a revision of the planning and design criteria but also the drafting of technical specifications for a distribution control centre which, among other functions, will serve to control 14 substations remotely. The studies included an analysis of the impact of a time-of-day tariff for industrial subscribers and the introduction of an objective rate structure for this type of customer.

A specialist in the civil engineering of dams contributed to the work of an international committee of experts set up by *Empresas de Energía Eléctrica de Bogotá* (EEEB), furnishing advice on technical aspects of the Guavio project. This project involves a hydroelectric generating station and two 230-kV transmission lines running the 100 km between the generating station and EEEB's main electric grid.



PERU

The study undertaken in 1987 on the harmonics of *Electroperú's* transmission system near Lima was completed.

The harmonics were caused by arc-furnace operations at the *Pisco* steel plant 200 km south of Lima. The aim of the investigation by TAI's power system studies specialists was to analyse the current and voltage distortion due to harmonics at critical points on the north-central power system. Different methods of reducing the level of these harmonics to within a pre-established range were recommended.



VENEZUELA

In collaboration with the firm *BELT*, technical assistance was provided to *Electrificación del Caroni* in the engineering, management, operation and maintenance of 800-kV lines and related substations.

This assistance took the form of a study of transformer faults and failures of shielded busbars at Guri generating station between the secondary side of the transformers and the conductors of the 800-kV lines, as well as specifications for 115-kV static compensators. HQI proposed solutions and performed the follow-up of modifications made to the equipment by manufacturers.

ACTIVITIES RELATED TO THE FRANCOPHONE SUMMIT



As a result of the summit of French-speaking nations, Hydro-Québec launched a cooperation and training program for electrical utilities in September 1987 at the request of the Government of Québec. The objective is to make Hydro-Québec's technological expertise and administrative know-how available to help other utilities meet their needs in fields such as power system planning, operation and management. Hydro-Québec has earmarked \$5 million for this five-year program, which is managed by HQL.

In addition, training and cooperation projects have been carried out in various French-speaking countries in Africa, notably the following:

- A seminar on the main environmental considerations related to the development of the electricity sector in Africa was held in Abidjan, Ivory Coast, with the participation of 25 African countries.
- Two other seminars on the high-technology aspects of HV transmission were held in Morocco and Tunisia for specialists from both countries.
- Technical and administrative studies, analyses and diagnostics were performed in Cameroon, the Ivory Coast, Guinea, Senegal and Togo.
- An office automation and data processing study was carried out for the Agency for Cultural and Technical Cooperation, the international body responsible for implementing decisions made at Francophone summits.

National and international awards were bestowed on TAI personnel during the course of 1988.

ROYAL SOCIETY OF CANADA

Raymond Bartnikas, research fellow, *Vice-présidence Recherche* (Research), was elected a member of the Royal Society of Canada for his exceptional contribution to electrical engineering, in particular for his studies on electrical insulation and dielectric losses.

CANADA COUNCIL

William-Henri Gauvin, chemical engineer and consultant in the area of industrial plasmas at LTEE, won the Canada Council's Isaac-Walton-Killam prize in recognition of his outstanding contribution to engineering.

PRIX MICA

Paul Héroux and Guy Ross earned the Québec government's 1988 Mica Grande Entreprise prize for the development of a dosimeter, an instrument designed for measuring electric, magnetic and electromagnetic fields created by high-voltage power lines. At the time of the development, Mr. Héroux was a research scientist and Mr. Ross, Division Head, Instrumentation Management.

IEEE POWER ENGINEERING SOCIETY

Yves Latour, André Petit, researchers, *Service Appareillage Électrique* (Electrical Apparatus), Guy St-Jean, Manager of this department, and Hieu Huynh, Division Head, *Vice-présidence Planification du réseau* (Equipment Planning), won the Prize Paper Award of the Power Engineering Society of IEEE for their 1987 noteworthy paper entitled "Qualification of Switchable Metal-Oxide Arresters for a Protective Level of 1.6 p.u. on Hydro-Québec's 735-kV System."

IEEE INNOVATION AWARD

Richard J. Marceau, generation technologies advisor, *Direction Planification de la technologie* (Technology Planning), won the IEEE 1987 Innovation Award for the way he organized the IEEE's participation in the Centenary of Canadian Engineering.

CONCORDIA UNIVERSITY

Ashok K. Vijh, research fellow, *Vice-présidence Recherche* (Research), was awarded the title of Doctor of Law, honoris causa, by Montreal's Concordia University.